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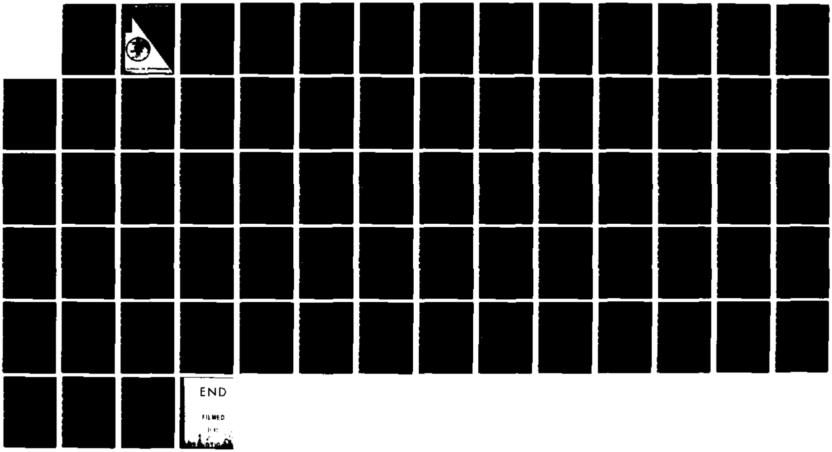

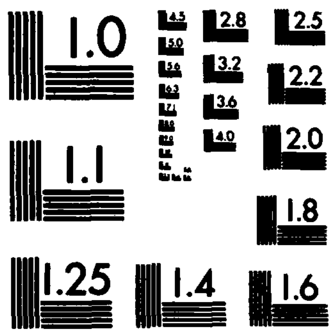

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CIVIL ENGINEERING DEPARTMENT

A CONSTRUCTION MANAGEMENT SYSTEM MICROCOMPUTER PROGRAM

by

Larry Elkins

A Report for

CE 598A - Civil Engineering Projects

Under Dr. S. W. Nunnally

Civil Engineering Department

North Carolina State University

Raleigh, N.C.

August 1983

SCHOOL OF ENGINEERING

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ABSTRACT

A microcomputer program is presented that enables a construction project manager to more effectively manage one or more construction projects. The objective of this construction management system program is to provide a comparison of planned and actual time and cost at any time throughout the project life. The program employs one of the most common network planning methods in use today, the Critical Path Method (CPM). The cost comparisons are obtained by utilizing the cost variance techniques of Pilcher. The program calculates CPM network values for the original planned and the actual networks as they are entered. Then the program compares durations and costs for each activity and provides a cost variance for all actual values that have been entered. A total project time, cost and profit variance is calculated. Also, any activity on the critical path can be crashed, thereby reducing project duration and increasing project direct cost. This program has been developed on an Intertec SuperBrain microcomputer system and is written in Microsoft's BASIC-80 computer programming language.

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CHAPTER 1

INTRODUCTION

1.1 The Contract Construction Industry

The contract construction industry is a very competitive industry, often resulting in a low profit margin and higher risks than in many other industries. After the work has started, contractors have to contend with restrictive labor agreements, adverse site conditions, price instability, and many other problems. Therefore, the need for accurate time and cost control is paramount, as is the need for feedback throughout the management chain. Owners and contractors recognize this need by requiring a detailed schedule of prices and work before project start-up. A growing number of owners, especially governmental agencies, are requiring this detailed schedule in the form of a CPM network. The CPM network is used to control time and cost.

1.2 The Project Manager

Most large construction contractors or owners, including governmental, have at least one or more project managers who are responsible for the time and cost management of one or more projects. A project manager continually monitors the progress of each project which includes:

1. A comparison of planned and actual durations and costs
2. Periodic reports to the owner or contractor

3. Consideration of whether an activity's duration needs to be decreased to keep the total project duration within allowable limits. This is accomplished by:

   (1) Overtime
   (2) A second shift
   (3) Another crew
   (4) Different or more equipment
   (5) Method improvement
   (6) Workforce adjustment

4. Use of historical data

It can be seen that each activity's progress and its resulting impact on the entire project must be ascertained as early as possible by the project manager in order to minimize losses in time and profit.

CHAPTER 2

THE CRITICAL PATH METHOD

2.1 Description

A brief description of the Critical Path Method (CPM) is provided in order that the construction management system may be fully utilized.

"A CPM network is a graphical representation of a project in which activities, the tasks that make up the project, are represented by arrows. The arrow tail and arrow head represent the start and finish of an activity, respectively" (1), as shown in Figure 1.

Figure 1. CPM Node Notation, after Ahuja (1)

Each activity is defined by two nodes or events, a tail node i and a head node j. Restrictions of this program model are that nodes are numbered in sequence where the i node number is always less than the j node number. Hence, the activities in Figure 2 are identified as activity 1-2, 2-3, 2-4, 3-5, and 4-5.

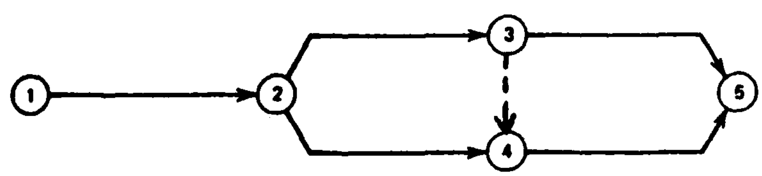


Figure 2. Typical CPM Node Sequence, after Ahuja (1)

2.2 Network Interrelationships

The precedence within a CPM network is indicated by entering the i node of the activity. All activities entering the i node of an activity must be completed before that activity can start. As in Figure 2, activity 1-2 must be completed before activity 2-3 or 2-4 can start. Sometimes relationships between activities cannot be shown by using regular activity arrows. The dummy represented by a dotted arrow is used for this purpose (Figure 2). A dummy has zero duration and involves no work. Two activities cannot have the same number; therefore, a dummy activity is used to clarify the situation as shown in Figure 3.

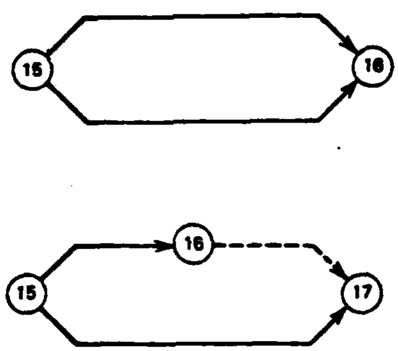


Figure 3. Use of a Dummy Activity, after Ahuja (1)

A network should have a consistent flow of activities from left to right and crossovers should be minimized.

2.3 Calculations

Various symbols, as shown in Fig - 4, c . be used to distinguish event times: i is the preceding node number and j the succeeding node

number. E is the early event time for a node or event and is defined as the earliest time an activity leaving that node can start. E=0 for the first node. L is the late event time for a node or event and is defined as the latest time an activity entering that node can finish. See Figure 5.

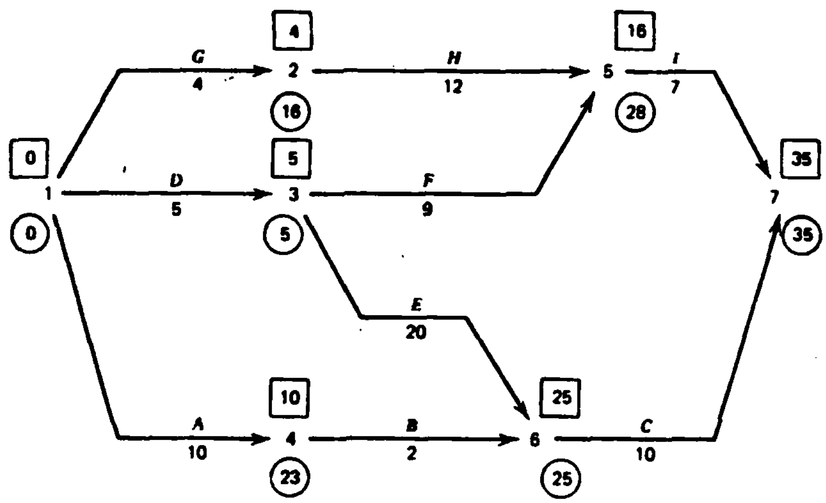


Figure 4. CPM Network Diagram, after Ahuja (1)

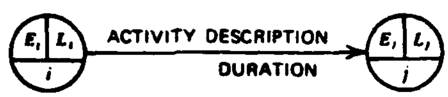


Figure 5. Activity Event Times, after Ahuja (1)

As shown in Figure 4, E_i for activity E and F is 5 and L_i for activity B is 23. The following equations define activity times:

Early Start (ES) $= E_i$ (1)

Early Finish (EF) $= E_i + D$ (duration) (2)

$$\text{Late Start (LS)} = L_j - D \qquad (3)$$

$$\text{Late Finish (LF)} = L_j \qquad (4)$$

"Total Float (TF) is defined as the amount of time an activity may be prolonged without extending the project completion date" (1) and is defined as follows:

$$TF = LF - ES - D \qquad (5)$$

or

$$TF = L_j - E_i - D \qquad (6)$$

"Free Float (FF) is defined as the amount of time an activity can be delayed without affecting the total float (TF) on the succeeding activities" (1).

$$FF = E_j - E_i - D \qquad (7)$$

or

$$FF = TF - IF \qquad (8)$$

Independent float is as follows:

$$IF = TF - FF \qquad (9)$$

or

$$IF = E_j - L_i - D \qquad (10)$$

A typical CPM diagram and the corresponding calculations are shown in Figure 4 and Table 1; activity descriptions are limited to letters (activity codes).

Table 1. CPM Network Calculations, after Ahuja (1)

Activity	Descrip-tion	Duration	Earliest Start	Earliest Finish	Latest Start	Latest Finish	Floats Total	Floats Free	Floats Independent
1–2	*G*	4	0	4	12	16	12	0	0
1–3	*D*	5	0	5	0	5	0	0	0
1–4	*A*	10	0	10	13	23	13	0	0
2–5	*H*	12	4	16	16	28	12	0	0*
3–5	*F*	9	5	14	19	28	14	2	2
3–6	*E*	20	5	25	5	25	0	0	0
4–6	*B*	2	10	12	23	25	13	13	0
5–7	*I*	7	16	23	28	35	12	12	0
6–7	*C*	10	25	35	25	35	0	0	0

* As mentioned earlier, if independent float calculations yield a negative value, the float is taken to be zero.

2.4 Critical Path Analysis

Ahuja (1) defines critical path as follows: "The chain of activities that takes the longest time to be completed determines the earliest time by which a project can be completed." An activity must meet the following criteria before it is considered critical:

1. $E_i = L_i$ (11)
2. $E_j = L_j$ (12)
3. $L_j - E_i - D = 0$ (13)

There can often be more than one critical path, so that decreasing the duration of one critical path will not necessarily decrease total project duration. Also, an increase in a noncritical activity duration may cause that activity and/or other activities to become critical. Any use of available total float can also affect other activities and floats.

In summary, the Critical Path Method (CPM) outlines clearly the execution of a project. It emphasizes the importance of system interrelationships and provides an important tool for construction management systems, especially when combined with cost variance within a microcomputer program.

CHAPTER 3

COST VARIANCE ANALYSIS

3.1 Description

The standards of cost by which a construction contract is controlled are of two types: indirect and direct planned or actual costs. This analysis focuses on direct costs related to each activity in the form of material and labor costs. Overhead costs (indirect) can be entered into the program for use in total project cost calculations but not for an individual activity.

3.2 Calculations

Calculations of the cost variance are made for material, labor, and budget costs for each activity and for the entire project. These costs are defined as follows:

a. Budget cost (BC) of the activity includes material, labor, and profit planned for that activity.

b. Planned material cost (PMC) is the cost of material only.

c. Planned labor cost (PLC) is the cost of labor only, which can include incentives.

d. Actual material cost (AMC).

e. Actual labor cost (ALC).

The cost variance (CV) for labor and material is then calculated for each activity as follows:

$$CV\ (\text{material}) = PMC - AMC \tag{14}$$

$$CV\ (\text{labor}) = PLC - ALC \tag{15}$$

$$CV\ (\%) = \frac{PMC - AMC}{PMC} \times 100 \tag{16}$$

or

$$CV\ (\%) = \frac{PLC - ALC}{PLC} \times 100 \tag{17}$$

Then the cost variance is calculated for the total project completed to date.

$$CV_T = PC_T - AC_T \tag{18}$$

$$CV_T(\%) = \frac{PC_T - AC_T}{PC_T} \tag{19}$$

PC = Planned Cost

AC = Actual Cost

At this point in the program, planned and actual on-site and general (office) overheads can be entered. Then the planned profit (PP) and the expected profit to date (EP) are calculated. If an activity is not complete, the planned costs are used instead of the actual costs for expected profit.

$$PP_T = BC_T - PMC_T - PLC_T - POOH - PGOH \tag{20}$$

$$EP_T = BC_T - AMC_T - ALC_T - AOOH - AGOH - IC \tag{21}$$

$$PP_T\ (\%) = \frac{PP}{BC_T} \times 100 \tag{22}$$

$$EP_T\ (\%) = \frac{EP}{BC_T} \times 100 \qquad (23)$$

T = Total project

POOH = Planned on-site overhead

PGOH = Planned general overhead

AOOH = Actual on-site overhead to date

AGOH = Actual general overhead to date

IC = Incremental crash cost, which is the expected cost increase if the duration is decreased by methods listed in section 1.2.

As shown in Table 2 and in the output section of Example 1, the cost variance for each activity and for the total project is calculated. The value of work done as listed in Table 2 is the planned material and labor costs.

It can be seen from Table 2 and Example 1 that, as the project progresses, such an analysis would reveal any cost problems that would require a project manager's attention.

Table 2. Contract Cost Variance Analysis, after Pilcher (2)

Budget cost report for contract CB185—October 1972. Total contract value: £273 000

Element of cost		Total value of work	Cumulative					Month			
Cost code no.	Description		Budgeted value of work done	Value of work done	Actual cost of work done	Variance	Variance	Value of work done	Actual cost of work done	Variance	Variance
		£	£	£	£	£	%	£	£	£	%
	Direct Labour										
003	Excavation to foundations	18 734	7 328	6 243	6 947	(704)	(11·28)	2 731	2 842	(111)	(4·06)
006	Excavation to drains	9 376	1 260	1 360	1 240	120	8·82	563	530	33	5·86
017	Concrete blinding	1 020	90	98	102	(4)	(4·08)	60	80	(20)	(33·33)
	Direct Materials										
117	Concrete aggregates	3 700	80	90	80	10	11·11	50	60	(10)	(20)
	Plant										
203	Excavation to foundations	31 670	10 346	9 207	9 500	(293)	(3·18)	5 346	5 200	146	2·73
206	Excavation to drains	25 600	2 341	2 460	2 370	90	3·66	1 026	900	126	12·28
	Totals—Labour, materials and plant	90 000	21 445	19 458	20 239	(781)	(4·01)	9 776	9 612	164	1·68
997	Site oncosts	9 500	2 450	2 500	2 400	100	4	1 050	1 250	(200)	(19·04)
998	H.O. overheads	4 500	1 100	1 200	1 060	140	11·67	570	550	20	3·51
999	Profit	9 000	2 400	2 500	2 390	110	4·40	960	957	3	0·31
	Totals	113 000	27 395	25 658	26 089	(431)	(1·68)	12 356	12 369	(13)	(0·11)

CHAPTER 4

MICROCOMPUTER PROGRAM

4.1 Program Description

The microcomputer program has been developed on an Intertec SuperBrain microcomputer system and is written in Microsoft's BASIC-80 language. The data input to the program includes:

a. A planned CPM network with the following data for each activity:

(1) activity code: a 1-3 letter code that represents a description. E.g.: AAA. See Table 3, Example 1

(2) i node number ($1 \leq i \leq 999$)

(3) j node number ($j > i$)($1 \leq j \leq 999$)

(4) Planned duration ($0.0 \leq D \leq 999.9$)

(5) Budgeted cost in whole dollars is the planned material, labor, and profit cost.

($0 \leq BC \leq 999999$) ($BC = PP + PMC + PLC$)

(6) Crash time is the new duration of the activity if crashed. ($0.0 \leq CT \leq 999.9$) ($CT \leq D$). E.g.: plan duration = 23.1 days; if it can be crashed 3 days, then CT = 20.1 days.

(7) Crash cost is the new cost of the activity if crashed to the new crash time in whole dollars.

($0 \leq CC \leq 999999$) ($CC \leq BC$). E.g.: budget cost = 15000; if it costs 2000 to be crashed 3 days (CT), then crash cost = 17000.

(8) Planned material cost in whole dollars.

$(0 \leq PMC \leq 999999)$

(9) Planned labor cost in whole dollars $(0 \leq PLC \leq 999999)$

$(PMC + PLC \leq BC)$

b. Actual data for each activity can be entered anytime:

(1) Actual duration.

$(0.0 \leq AD \leq 999.9)$

(2) Actual material cost in whole dollars.

$(0 \leq AMC \leq 999999)$

(3) Actual labor cost in whole dollars.

$(0 \leq ALC \leq 999999)$

c. Overhead data for the entire project are entered but not stored:

(1) Planned on-site overhead in whole dollars per day (\$/day).

$(0 \leq PO \leq 99999)$

(2) Planned general (office) overhead in whole dollars (\$).

$(0 \leq PG \leq 999999)$

(3) Actual or expected on-site overhead in whole dollars per day (\$/day).

$(0 \leq AO \leq 99999)$

(4) Actual or expected general overhead in whole dollars (\$).

$(0 \leq AG \leq 999999)$

Selective crashing is the decrease of an activity duration with a corresponding increase in cost. The difference between the plan duration and the crash time is the amount of time that an activity can

be crashed. The difference in the budget cost and the crash cost is the expected cost of crashing. This program calculates the total cost of crashing and the unit cost in dollars per day. When all or a portion of the total cost of crashing is entered, then a new duration is calculated for that activity. This, in turn, changes the project duration, increases cost, and decreases profit but may be required in order to meet contract requirements.

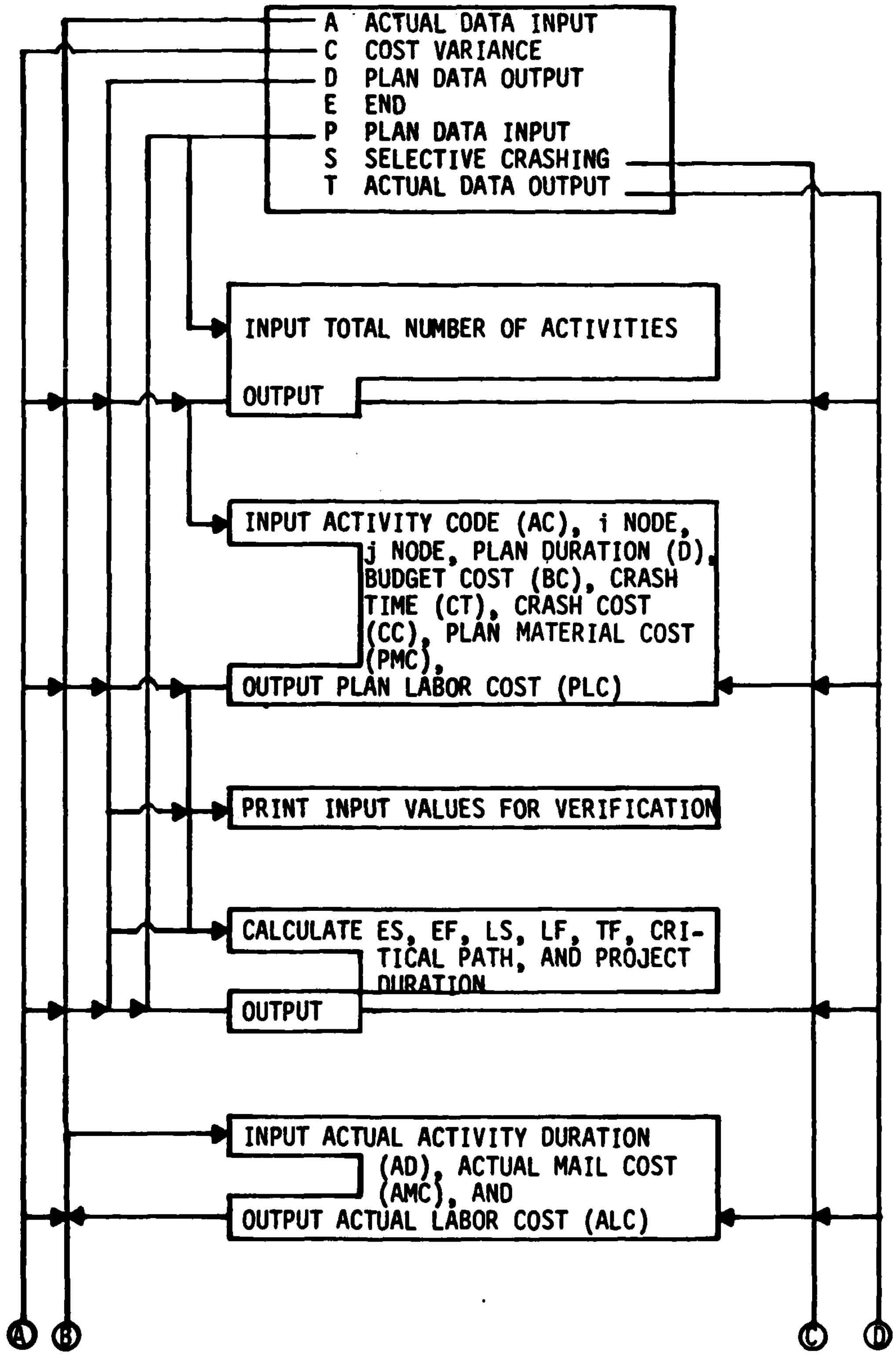
Selective crashing data can be entered at anytime for activities on the critical path. A unit cost in whole dollars per day and a total incremental cost that can be crashed is shown. Activity number and crash amount are entered with the resulting decrease in duration used for time and cost variance calculations. Crashing data are not stored. CPM network and cost variance calculations are performed as indicated in Chapters 2 and 3.

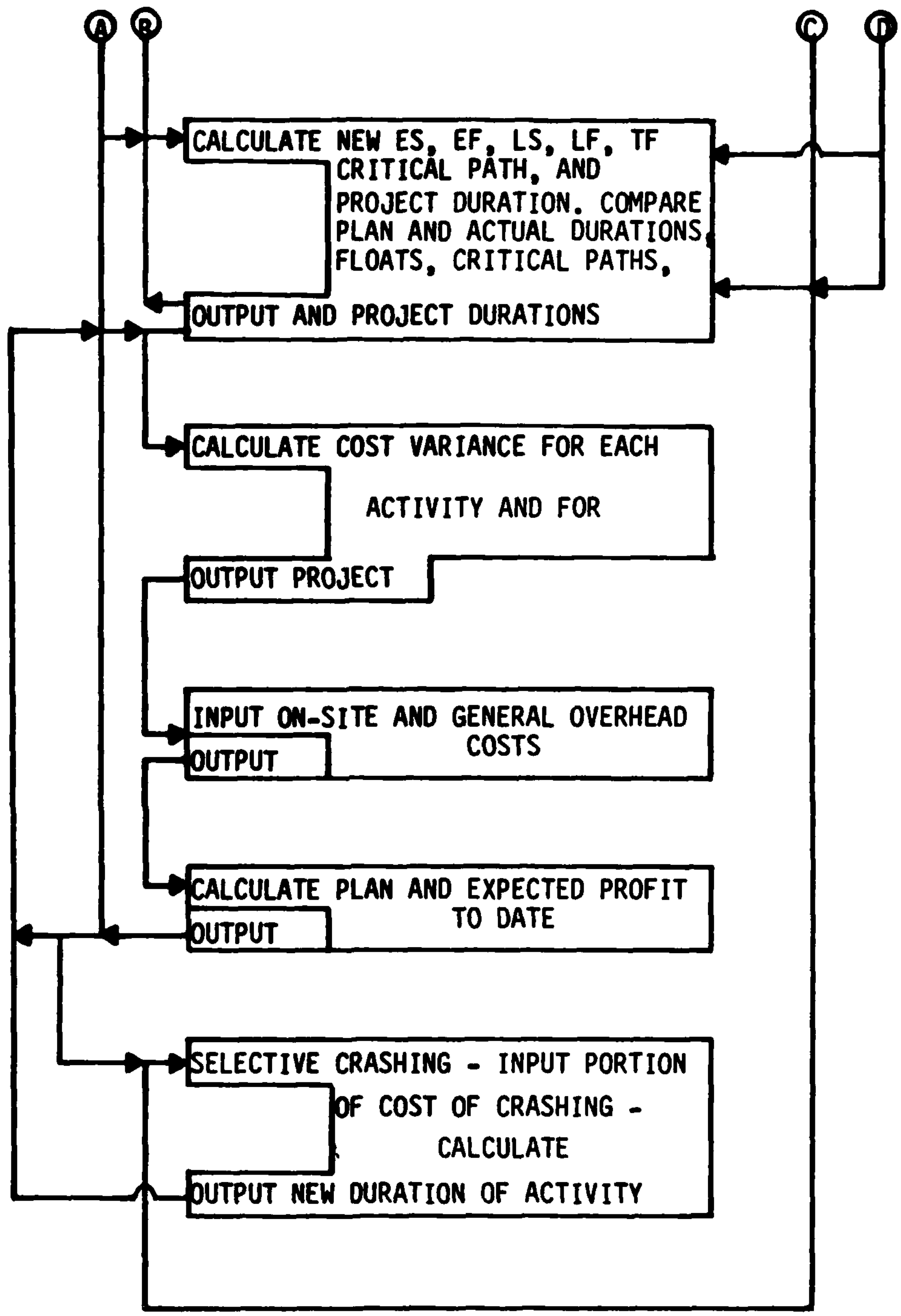
The output consists of: CPM network data verification; CPM event calculations of ES, EF, LS, LF, TF, and critical path for each activity; total project duration.

Upon input of actual duration and costs of activities, the above values are recalculated (output) and a time and cost variance is computed.

Computer instructions will appear on the screen, indicating step by step the kind of data that are required and the options available to the user.

4.2 Program Flow Chart




A
B
C
D
CALCULATE NEW ES, EF, LS, LF, TF CRITICAL PATH, AND PROJECT DURATION. COMPARE PLAN AND ACTUAL DURATIONS, FLOATS, CRITICAL PATHS,
OUTPUT AND PROJECT DURATIONS
CALCULATE COST VARIANCE FOR EACH ACTIVITY AND FOR
OUTPUT PROJECT
INPUT ON-SITE AND GENERAL OVERHEAD COSTS
OUTPUT
CALCULATE PLAN AND EXPECTED PROFIT TO DATE
OUTPUT
SELECTIVE CRASHING - INPUT PORTION OF COST OF CRASHING - CALCULATE
OUTPUT NEW DURATION OF ACTIVITY

4.3 Program Listing

```
10 REM  "CMS"
20 PRINT" CONSTRUCTION MANAGEMENT SYSTEM BASED ON CPM TIME/COST"
25 DIM A$(99,1),A(99,17),B(99,10),SV(12)
27 PRINT"  "
30 PRINT"      MENU"
40 PRINT"  "
50 PRINT"       A    ACTUAL DATA INPUT(INCLUDES PLAN REVIEW & TIME VARIANCE)"
60 PRINT"       C    COST VARIANCE TO DATE"
70 PRINT"       D    PLAN DATA OUTPUT"
80 PRINT"       E    END"
90 PRINT"       P    PLAN DATA INPUT"
100 PRINT"       S    SELECTIVE CRASHING(INCLUDES ACTUAL DATA RUN TO DATE)"
110 PRINT"       T    ACTUAL DATA OUTPUT TO DATE(TIME VARIANCE)"
120 PRINT"  "
130 INPUT"SELECTION";IO$
140 IF IO$="E" THEN END
145 RC=0:SC=0:SS=0
150 IF IO$<>"P" THEN GOTO 220
160 OPEN "R",#1,"B:NUMBER",3
170 FIELD #1, 3 AS M$
180 INPUT"TOTAL NUMBER OF ACTIVITIES";M%
190 LSET M$=MKI$(M%)
200 PUT #1,1
210 CLOSE #1,1
220 OPEN "R",#1,"B:NUMBER",3
230 FIELD #1, 3 AS M$
235 GET #1,1
240 M%=CVI(M$)
```

```
250 CLOSE #1,1
270 IF IO$<>"P" THEN GOTO 510
280 OPEN "R",#2,"B:PLAN",43
290 FIELD #2, 3 AS B$, 3 AS D$, 3 AS E$, 5 AS F$, 6 AS G$, 5 AS H$, 6 AS N$, 6
S O$, 6 AS P$
292 FOR I=1 TO M%
296 IF I<>1 THEN GOTO 310
300 PRINT"*** EVENTS MUST BE INPUTTED IN NUMERICAL ORDER BY i NODE & j NODE **
303 PRINT"  "
305 PRINT"INPUT-ACTIVITY CODE(AC), i NODE, j NODE,DURATION(D),BUDGET COST(BC),'
306 PRINT"CRASH TIME(CT),CRASH COST(CC),PLAN MATL COST(PMC),AND LABOR COST(PLC
"
308 PRINT"  "
310 INPUT" AC,i,j,D,BC,CT,CC,PMC,PLC";A$(I,1),A(I,1),A(I,2),A(I,3),A(I,4),A(I,5
,A(I,6),B(I,1),B(I,2)
320 LSET B$=A$(I,1)
340 LSET D$=MKI$(A(I,1))
350 LSET E$=MKI$(A(I,2))
360 LSET F$=MKS$(A(I,3))
370 LSET G$=MKI$(A(I,4))
380 LSET H$=MKS$(A(I,5))
390 LSET N$=MKI$(A(I,6))
400 LSET O$=MKI$(B(I,1))
410 LSET P$=MKI$(B(I,2))
440 PUT #2,I
470 IF I=L THEN GOTO 510
480 NEXT I
```

```
480 NEXT I
510 CLOSE #2
520 OPEN "R",#2,"B:PLAN",43
530 FIELD #2, 3 AS B$, 3 AS D$, 3 AS E$, 5 AS F$, 6 AS G$, 5 AS H$, 6 AS N$, 6
S O$, 6 AS P$
540 FOR I=1 TO M%
560 GET #2,I
570 A$(I,1)=B$
590 A(I,1)=CVI(D$)
600 A(I,2)=CVI(E$)
610 A(I,3)=CVS(F$)
620 A(I,4)=CVI(G$)
630 A(I,5)=CVS(H$)
640 A(I,6)=CVI(N$)
650 B(I,1)=CVI(O$)
660 B(I,2)=CVI(P$)
670 NEXT I
690 EE=0
700 REM PRINTS INPUT DATA FOR VERIFICATION
710 M=M%:TP=0:FOR I=1 TO M:IF A(I,2)>TP THEN TP=A(I,2)
720 NEXT:EE=TP
730 FOR I=1 TO M-1
740 FOR J=I+1 TO M
750 IF A(I,1)<=A(J,1) THEN 780
760 FOR K=1 TO 12:SV(K)=A(I,K):A(I,K)=A(J,K):A(J,K)=SV(K):NEXT K
770 FOR K=1 TO 2:SV$(K)=A$(I,K):A$(I,K)=A$(J,K):A$(J,K)=SV$(K):NEXT K
775 NEXT J,I
777 J=0
```

```
780 IF IO$="C" THEN GOTO 1285
782 IF IO$="S" THEN GOTO 1285
785 IF IO$="T" THEN GOTO 1285
788 PRINT" "
790 PRINT"                              VERIFICATION OF PLAN INPUT"
795 PRINT" "
800 Z1$="CODE     PLAN    EARLY    EARLY     LAST     LAST    TOTAL"
810 Z2$="          DUR    START    FINISH   START    FINISH   FLOAT"
820 Z3$="CODE  i    j       PLAN   BUDGET CRASH    CRASH    MATL   LABOR"
830 Z4$="     NODE NODE     DUR     COST   TIME     COST    COST    COST"
840 PRINT" NO ";Z3$
850 PRINT"    ";Z4$
880 FOR I=1 TO M%
890 PRINT USING "###  ";I;
900 PRINT USING "&";A$(I,1);
920 FOR J=1 TO 2
930 PRINT USING " ###";A(I,J);
940 NEXT J
945 PRINT USING"    ###.#";A(I,3);
950 PRINT USING" ######";A(I,4);
960 PRINT USING"  ###.#";A(I,5);
970 PRINT USING"  ######";A(I,6);
975 PRINT USING" ######";B(I,1),B(I,2)
980 IF I=20 THEN INPUT"ENTER TO CONTINUE";DU$
982 IF I=40 THEN INPUT"ENTER TO CONTINUE";DU$
984 IF I=60 THEN INPUT"ENTER TO CONTINUE";DU$
986 IF I=80 THEN INPUT"ENTER TO CONTINUE";DU$
990 NEXT I
```

```
990 NEXT I
995 IF IO$="A" THEN GOTO 1110
1000 INPUT" ENTER -1 TO CONTINUE OR NUMBER TO CHANGE";L:IF L=-1 THEN GOTO 1110
1010 I=0:IF L>.00001 THEN I=I+L ELSE GOTO 1000
1020 GOTO 305
1110 INPUT"HARD COPY OF INPUT DATA (Y/N)";HC$
1120 IF HC$<>"Y" THEN GOTO 1285
1125 LPRINT"  "
1130 INPUT"TITLE";T$:LPRINT"TITLE: ";T$
1140 INPUT"DATE";T$:LPRINT"DATE: ";T$
1145 LPRINT"  "
1150 LPRINT" NO ";Z3$
1160 LPRINT"    ";Z4$
1170 FOR I=1 TO M%
1180 LPRINT USING "###  ";I;
1190 LPRINT USING "&";A$(I,1);
1210 FOR J=1 TO 2
1220 LPRINT USING " ###";A(I,J);
1230 NEXT J
1235 LPRINT USING"    ###.#";A(I,3);
1240 LPRINT USING" ######";A(I,4);
1250 LPRINT USING"  ###.#";A(I,5);
1260 LPRINT USING"  ######";A(I,6);
1265 LPRINT USING " ######";B(I,1),B(I,2)
1280 NEXT I
1285 RC=0:FOR I=1 TO M%:A(I,13)=0:NEXT I
1290 REM NOW BEGINING EVENT IS 1 EARLY START=0 FORWARD PASS
1320 FOR I=1 TO M%:IF RC=0 THEN A(I,7)=A(I,3)
```

```
1325 IF RC=-1 THEN A(I,7)=A(I,15)
1340 NEXT I
1350 FOR I=1 TO M%
1360 IF A(I,1)=1 THEN A(I,8)=0:A(I,9)=A(I,7):GOTO 1440
1370 MAX=0!
1380 FOR J=1 TO M%
1390 IF A(J,2)<>A(I,1) THEN 1420
1400 IF A(J,9)>MAX THEN MAX=A(J,9)
1410 A(I,8)=MAX
1420 NEXT J
1430 A(I,9)=A(I,8)+A(I,7)
1440 NEXT I
1450 REM BACKWARD PASS
1460 XM=0
1470 FOR I=M% TO 1 STEP-1
1480 IF A(I,2)<>EE THEN 1510
1490 IF M%<A(I,9) THEN XM=A(M%,9)
1500 IF A(I,9)>A(M%,9) THEN XM=A(I,9)
1510 NEXT I
1520 FOR I=M% TO 1 STEP-1
1530 IF A(I,2)=EE THEN A(I,11)=XM:GOTO 1600
1540 MIM=99999!
1550 FOR J=M% TO 1 STEP-1
1560 IF A(I,2)<>A(J,1) THEN 1590
1570 IF A(J,10)<MIM THEN MIM=A(J,10)
1580 A(I,11)=MIM
1590 NEXT J
```

```
1590 NEXT J
1600 A(I,10)=A(I,11)-A(I,7)
1610 NEXT I
1620 REM TOTAL FLOAT CALCULATIONS
1630 FOR I=1 TO M%
1635 IF RC=-1 THEN A(I,17)=A(I,11)-A(I,9)
1640 IF RC=0 THEN A(I,12)=A(I,11)-A(I,9)
1650 NEXT I
1660 K=0:REM PRINT OUTPUT
1665 IF RC=-1 THEN GOTO 2620
1666 IF IO$="C" THEN GOTO 1960
1667 IF IO$="T" THEN GOTO 1960
1669 IF IO$="S" THEN GOTO 1960
1670 PRINT "  "
1675 PRINT"                                EVENT TIMES OF PLAN INPUT"
1678 PRINT"  "
1680 PRINT" NO ";Z1$
1690 PRINT"     ";Z2$
1700 FOR I=1 TO M%
1715 PRINT USING"###  ";I;
1720 PRINT USING "&";A$(I,1);
1740 FOR J=7 TO 12
1750 PRINT USING "   ###.# ";A(I,J);
1760 NEXT J
1770 PRINT
1772 IF I=20 THEN INPUT"ENTER TO CONTINUE";DU$
1774 IF I=40 THEN INPUT"ENTER TO CONTINUE";DU$
1776 IF I=60 THEN INPUT"ENTER TO CONTINUE";DU$
1778 IF I=80 THEN INPUT"ENTER TO CONTINUE";DU$
```

```
1780 NEXT I
1790 INPUT"HARD COPY OF RESULTS (Y/N)";HC$:IF HC$<>"Y" THEN 1960
1810 LPRINT"  "
1815 LPRINT"                              EVENT TIMES OF PLAN INPUT"
1817 LPRINT"  "
1820 LPRINT" NO ";Z1$
1830 LPRINT"    ";Z2$
1840 FOR I=1 TO M%
1855 LPRINT USING"###  ";I;
1860 LPRINT USING "&";A$(I,1);
1880 FOR J=7 TO 12
1890 LPRINT USING "   ###.# ";A(I,J);
1900 NEXT J
1910 LPRINT
1920 NEXT I
1960 REM IDENTIFICATION OF CRITICAL PATH AND COSTS
1970 CO=0:PATH$=" ":CX=0
1980 FOR I=1 TO M%:IF A(I,12)>.00001 THEN 2000
1990 PATH$=PATH$+" "+A$(I,1)
2000 CX=CX+A(I,4):NEXT I
2001 CO=A(M%,11)
2002 IF IO$="C" THEN GOTO 2340
2003 IF IO$="S" THEN GOTO 2340
2005 IF IO$="T" THEN GOTO 2340
2007 PRINT" "
2010 PRINT"PLAN CRITICAL PATH: ";:PRINT PATH$
2060 PRINT "PLAN PROJECT DURATION: ";CO
2070 PRINT "BUDGET COST OF PROJECT: ";CX
```

```
2070 PRINT "BUDGET COST OF PROJECT: ";CX
2080 PRINT"  "
2090 INPUT"HARD COPY OF RESULTS (Y/N)";HC$
2095 IF HC$<>"Y" THEN GOTO 2190
2098 LPRINT"  "
2100 LPRINT"PLAN CRITICAL PATH: ";PATH$
2110 LPRINT"PLAN PROJECT DURATION: ";CO
2120 LPRINT"BUDGET COST OF PROJECT: ";CX
2190 IF IO$="A" THEN GOTO 2210
2195 IF IO$="S" THEN GOTO 3930
2200 GOTO 30
2210 REM ACTUAL DATA INPUT
2215 PRINT"                    ***   BEGIN ACTUAL DATA INPUT   ***"
2240 OPEN "R",#3,"B:ACTUAL",17
2250 FIELD #3, 5 AS Q$, 6 AS U$, 6 AS V$
2253 INPUT"NUMBER OF NEXT ACTIVITY FOR ACTUAL DATA INPUT";NA
2255 I=NA
2260 INPUT"INPUT-ACTUAL DURATION,MATL COST,AND LABOR COST";A(I,14),B(I,3),B(I,
2270 LSET Q$=MKS$(A(I,14))
2280 LSET U$=MKI$(B(I,3))
2290 LSET V$=MKI$(B(I,4))
2300 PUT #3,I
2320 INPUT"ENTER -1 FOR REVISED CPM OR -2 TO CONTINUE INPUT";RC
2330 IF RC<>-1 THEN 2253
2340 CLOSE #3
2400 OPEN "R",#3,"B:ACTUAL",17
2430 FIELD #3, 5 AS Q$, 6 AS U$, 6 AS V$
2435 FOR I=1 TO M%
2440 GET #3,I
2450 A(I,14)=CVS(Q$)
```

```
2460 B(I,3)=CVI(U$)
2470 B(I,4)=CVI(V$)
2480 NEXT I
2490 CLOSE #3
2500 FOR I=1 TO M%
2520 IF A(I,14)>.00001 THEN A(I,15)=A(I,14):GOTO 2550
2530 A(I,15)=A(I,3)
2550 A(I,16)=A(I,15)-A(I,3)
2560 NEXT I
2580 IF IO$="S" THEN RC=-1
2590 IF IO$="T" THEN RC=-1
2595 IF IO$="C" THEN RC=-1
2600 GOTO 1290
2620 PRINT"  ":IF IO$="C" THEN GOTO 2900
2630 PRINT"                    ACTUAL DATA RUN TO DATE                      "
2633 IF SC=1 THEN PRINT"                    WITH SELECTIVE CRASHING"
2635 PRINT"  "
2640 Z5$="CODE  PLAN  ACTUAL        EARLY EARLY  LAST  LAST ACTUAL PLAN"
2650 Z6$="       DUR   DUR    DIFF  START  FIN  START  FIN  FLOAT FLOAT"
2660 PRINT" NO ";Z5$
2670 PRINT"    ";Z6$
2680 FOR I=1 TO M%
2690 PRINT USING"###  ";I;
2700 PRINT USING"&";A$(I,1);
2720 PRINT USING"####.# ";A(I,3),A(I,7),A(I,16);
2730 FOR J=8 TO 11
2740 PRINT USING" ###.#";A(I,J);
2750 NEXT J
2755 PRINT USING"  ##.#";A(I,17),A(I,12);
2760 PRINT
```

```
2760 PRINT
2762 IF I=20 THEN INPUT"ENTER TO CONTINUE";DU$
2764 IF I=40 THEN INPUT"ENTER TO CONTINUE";DU$
2766 IF I=60 THEN INPUT"ENTER TO CONTINUE";DU$
2768 IF I=80 THEN INPUT"ENTER TO CONTINUE";DU$
2770 NEXT I
2790 INPUT"HARD COPY OF RESULTS (Y/N)";HC$
2800 IF HC$<>"Y" THEN GOTO 2900
2810 LPRINT"  "
2820 LPRINT"                          ACTUAL DATA RUN TO DATE          "
2825 IF SC=1 THEN LPRINT"                          WITH SELECTIVE CRASHING"
2830 LPRINT"  ":LPRINT" NO ";Z5$:LPRINT"    ";Z6$
2840 FOR I=1 TO M%
2850 LPRINT USING"###  ";I;:LPRINT USING"&";A$(I,1);
2870 LPRINT USING"####.# ";A(I,3),A(I,7),A(I,16);
2875 FOR J=8 TO 11
2880 LPRINT USING" ###.#";A(I,J);
2885 NEXT J
2888 LPRINT USING"  ##.#";A(I,17),A(I,12);
2890 LPRINT
2895 NEXT I
2900 REM IDENTIFICATION OF CRITICAL PATH
2910 ECP$=" ":PO=0
2920 FOR I=1 TO M%:IF A(I,17)>.00001 THEN 2940
2930 ECP$=ECP$+" "+A$(I,1)
2940 NEXT I
2942 PO=A(M%,11)
2945 IF IO$="C" THEN GOTO 3100
```

```
2950 PRINT"  "
2960 PRINT"ACTUAL CRITICAL PATH NOW:";:PRINT ECP$:IF SC=1 THEN PRINT" (WITH SE
CTIVE CRASHING)"
2965 PRINT"PLAN CRITICAL PATH:";:PRINT PATH$
2970 PRINT"EXPECTED PROJECT DURATION TO DATE: ";PO:IF SC=1 THEN PRINT" (WITH S
ECTIVE CRASHING)"
2980 PRINT"           ORIGINAL PLAN DURATION: ";CO:PRINT"  "
2990 IF IO$="C" THEN GOTO 3510
3010 INPUT"HARD COPY OF RESULTS (Y/N)";HC$
3020 IF HC$<>"Y" THEN GOTO 3080
3030 LPRINT"  "
3040 LPRINT"ACTUAL CRITICAL PATH NOW:";:LPRINT ECP$:IF SC=1 THEN LPRINT" (WITH
ELECTIVE CRASHING)"
3050 LPRINT"PLAN CRITICAL PATH:";:LPRINT PATH$
3060 LPRINT"EXPECTED PROJECT DURATION TO DATE: ";PO:IF SC=1 THEN LPRINT" (WITH
ELECTIVE CRASHING)"
3070 LPRINT"           ORIGINAL PLAN DURATION: ";CO:LPRINT"  "
3071 INPUT"ENTER TO CONTINUE";DU$
3072 IF SS=2 THEN GOTO 3828
3075 IF IO$="C" THEN GOTO 3828
3080 IF SC=1 THEN GOTO 3100
3085 IF IO$="S" THEN GOTO 3930
3090 GOTO 30
3100 FOR I=1 TO M%
3110 IF B(I,3)>.00001 THEN B(I,5)=B(I,3):GOTO 3130
3120 B(I,5)=B(I,1)
3130 B(I,7)=B(I,5)-B(I,1)
3140 IF B(I,1)>.00001 THEN B(I,8)=(B(I,7)/B(I,1))*100
3150 NEXT I
```

```
3150 NEXT I
3160 FOR I=1 TO M%
3170 IF B(I,4)>.00001 THEN B(I,6)=B(I,4):GOTO 3190
3180 B(I,6)=B(I,2)
3190 B(I,9)=B(I,6)-B(I,2)
3200 IF B(I,2)>.00001 THEN B(I,10)=(B(I,9)/B(I,2))*100
3210 NEXT I
3230 REM COST VARIANCE TO DATE
3250 PRINT"  "
3260 PRINT"                              COST VARIANCE TO DATE"
3265 IF IO$="S" THEN PRINT"                              WITH SELECTIVE CRASHING"
3270 PRINT"  "
3280 Z7$="            ACT   PLAN   PLAN   ACT   MATL  MATL   PLAN   ACT  LABOR LA
OR"
3290 Z8$=" NO CODE   DUR  BUDGT   MATL   MATL  COST   %     LABOR  LABOR COST
%"
3300 Z9$="            DIFF  COST   COST   COST  DIFF  DIFF   COST   COST  DIFF  I
FF"
3310 PRINT Z7$
3320 PRINT Z8$
3330 PRINT Z9$
3335 PB=0:PM=0:AM=0:MC=0:PL=0:AL=0:LC=0
3340 FOR I=1 TO M%
3345 PRINT USING"###  ";I;
3350 PRINT USING"&";A$(I,1);
3370 PRINT USING" ##.#";A(I,16);
3380 PRINT USING" ######";A(I,4),B(I,1),B(I,5);
3390 PRINT USING" #####";B(I,7);
```

```
3400 PRINT USING"####.#";B(I,8);
3410 PRINT USING" ######";B(I,2),B(I,6);
3420 PRINT USING" #####";B(I,9);
3430 PRINT USING"####.#";B(I,10)
3435 IF I=20 THEN INPUT"ENTER TO CONTINUE";DU$
3440 IF I=40 THEN INPUT"ENTER TO CONTINUE";DU$
3443 IF I=60 THEN INPUT"ENTER TO CONTINUE";DU$
3446 IF I=80 THEN INPUT"ENTER TO CONTINUE";DU$
3450 PB=PB+A(I,4):PM=PM+B(I,1):AM=AM+B(I,5):MC=MC+B(I,7):PL=PL+B(I,2):AL=AL+B(
6):LC=LC+B(I,9)
3460 NEXT I
3470 PRINT"-------------------------------------------------------------------------
---"
3475 MD=MC/PM*100:LD=LC/PL*100
3480 PRINT"TOTALS  ";:PRINT"      ";:PRINT USING"#######";PB,PM,AM;:PRINT USING
#####";MC;:PRINT USING"####.#";MD;:PRINT USING"#####
#";PL,AL;:PRINT USING"######";LC;:PRINT USING"####.#";LD
3490 IF SC=1 THEN GOTO 3505
3500 GOTO 2950
3505 IF IO$="S" THEN PRINT"INCREMENTAL CRASH COST FOR PROJECT: $";IC
3510 INPUT"ACTUAL ON-SITE OVERHEAD COST($/DAY)";SO
3515 INPUT"PLAN ON-SITE OVERHEAD COST($/DAY)";OO
3520 INPUT"ACTUAL ANTICIPATED GENERAL OVERHEAD COST FOR PROJECT($)";GO
3525 INPUT"PLAN GENERAL OVERHEAD COST FOR PROJECT($)";PG
3530 OC=SO*PO
3535 POC=OO*PO
```

```
3535 POC=OO*PO
3540 PRINT"  "
3550 PRINT"EXPECTED ON-SITE OVERHEAD TO DATE: $";OC:IF SC=1 THEN PRINT" (WITH
LECTIVE CRASHING)"
3555 PRINT"PLAN ON-SITE OVERHEAD COST: $";POC
3560 PRINT"ANTICIPATED GENERAL OVERHEAD TO DATE: $";GO
3565 PRINT"PLAN GENERAL OVERHEAD COST: $";PG
3570 PF=PB-OC-GO-AM-AL-IC:IF PB>.00001 THEN PF=PF/PB*100
3575 PT=PB-POC-PG-PM-PL:PI=PT/PB*100
3580 PRINT"  "
3590 PRINT"EXPECTED PROFIT TO DATE: $";PF:IF SC=1 THEN PRINT" (WITH SELECTIVE
ASHING)"
3595 PRINT"PLAN PROFIT: $";PT
3600 PRINT"EXPECTED PERCENT PROFIT TO DATE: ";:PRINT USING"####.##";PF:IF SC=1
HEN PRINT" (WITH SELECTIVE CRASHING)"
3605 PRINT"PLAN PERCENT PROFIT: ";:PRINT USING"####.##";PI
3607 PRINT"  "
3610 INPUT"HARD COPY OF RESULTS(Y/N)";HC$
3620 IF HC$<>"Y" THEN GOTO 3900
3630 LPRINT"  "
3640 LPRINT"                              COST VARIANCE TO DATE"
3645 IF IO$="S" THEN LPRINT"                              WITH SELECTIVE CRASHING"
3650 LPRINT"  "
3660 LPRINT Z7$:LPRINT Z8$:LPRINT Z9$
3670 FOR I=1 TO M%
3680 LPRINT USING"###  ";I;:LPRINT USING"&";A$(I,1);
3700 LPRINT USING" ##.#";A(I,16);
3710 LPRINT USING" ######";A(I,4),B(I,1),B(I,5);
3720 LPRINT USING" #####";B(I,7);
```

```
3730 LPRINT USING"####.#";B(I,8);
3740 LPRINT USING" ######";B(I,2),B(I,6);
3750 LPRINT USING" #####";B(I,9);
3760 LPRINT USING"####.#";B(I,10)
3780 NEXT I
3790 LPRINT"--------------------------------------------------------------------
----"
3800 LPRINT"TOTALS  ";:LPRINT"     ";:LPRINT USING"#######";PB,PM,AM;:LPRINT L
NG"######";MC;:LPRINT USING"####.#";MD;:LPRINT USING
"#######";PL,AL;:LPRINT USING"######";LC;:LPRINT USING"####.#";LD
3820 LPRINT"  "
3822 IF SC=1 THEN SS=2
3825 GOTO 3040
3829 IF IO$="S" THEN LPRINT"INCREMENTAL CRASH COST FOR PROJECT: $";IC
3830 LPRINT"EXPECTED ON-SITE OVERHEAD TO DATE: $";OC:IF SC=1 THEN LPRINT" (WIT
SELECTIVE CRASHING)"
3835 LPRINT"PLAN ON-SITE OVERHEAD COST: $";POC
3840 LPRINT"ANTICIPATED GENERAL OVERHEAD TO DATE: $";GO
3845 LPRINT"PLAN GENERAL OVERHEAD COST: $";PG
3850 LPRINT"  ":LPRINT"EXPECTED PROFIT TO DATE: $";PF:IF SC=1 THEN LPRINT" (WI
 SELECTIVE CRASHING)"
3855 LPRINT"PLAN PROFIT: $";PT
3860 LPRINT"EXPECTED PERCENT PROFIT TO DATE: ";:LPRINT USING"####.##";PP:IF SC
 THEN LPRINT" (WITH SELECTIVE CRASHING)"
3880 LPRINT"PLAN PERCENT PROFIT: ";:LPRINT USING"####.##";PI:LPRINT"  "
3900 GOTO 30
```

```
3900 GOTO 30
3930 PRINT" NO CODE     SELECT     CRASH        UNIT       TOTAL"
3940 PRINT"                TIME       COST        COST        COST "
3970 FOR I=1 TO M%:X=0:Y=0:IF A(I,13)=0 AND A(I,17)>.00001 THEN 4010
3980 IF A(I,3)>.00001 AND (A(I,3)-A(I,5))>.00001 THEN X=(A(I,6)-A(I,4))/(A(I,3
A(I,5))
3985 IF A(I,6)>.00001 THEN Y=A(I,6)-A(I,4)
3990 PRINT USING "###  ";I;:PRINT USING "&";A$(I,1);:PRINT USING "  ######   "
(I,7),A(I,13),X,Y
4010 NEXT I
4030 INPUT"-1 TO CONTINUE,-2 TO RECYCLE, OR NUMBER TO CRASH";IZ:IF IZ=-1 THEN
TO 4110
4035 IF IZ=-2 THEN GOTO 30
4040 IF A(IZ,14)>.00001 THEN PRINT"*** ACTIVITY COMPLETED TO DATE-CANNOT CRASH
**":GOTO 4090
4050 INPUT"CRASH DOLLARS OVER NORMAL DOLLARS";CD:X=A(IZ,3)-A(IZ,5):TS=CD/((A(I
6)-A(IZ,4))/X):IF TS>X THEN TS=X:INPUT "WASTED MONEY
 ENTER TO CONTINUE";DU$:GOTO 3930
4070 A(IZ,7)=A(IZ,7)-TS:IF A(IZ,7)<A(IZ,5) THEN A(IZ,7)=A(IZ,5):INPUT"OVER CRA
ED -- ENTER TO CONTINUE";DU$:A(IZ,7)=A(IZ,7)+TS:GOTO
3930
4080 A(IZ,13)=CD:IC=IC+CD:A(IZ,16)=-TS
4090 GOTO 3930
4110 INPUT"HARD COPY(Y/N)";DU$:IF DU$="N" THEN SC=1:GOTO 1350
4120 LPRINT"  "
4130 LPRINT" NO CODE     SELECT     CRASH        UNIT       TOTAL"
4140 LPRINT"                TIME       COST        COST        COST "
4150 X=0:Y=0
```

```
4170 FOR I=1 TO M%:IF A(I,13)=0 AND A(I,17)>.00001 THEN GOTO 4230
4180 IF A(I,3)>.00001 AND (A(I,3)-A(I,5))>.00001 THEN X=(A(I,6)-A(I,4))/(A(I,3
A(I,5))
4185 IF A(I,6)>.00001 THEN Y=A(I,6)-A(I,4)
4190 LPRINT USING"###  ";I;:LPRINT USING"&";A$(I,1);:LPRINT USING"  ######
(1,7),A(I,13),X,Y
4230 NEXT I
4240 INPUT"ENTER -1 TO RECYCLE OR -2 TO CONTINUE";TU:IF TU=-1 THEN GOTO 30
4250 SC=1
4270 GOTO 1350
```

4.4 Notation of the Variables Used

M% = total number of activities

I = activity number

A$(I,1) = activity code description (AC)

A(I,1) = i node number (i) of an activity

A(I,2) = j node number (j) of an activity

A(I,3) = plan duration (D) of an activity

A(I,4) = budget cost (BC) of an activity

A(I,5) = crash time (CT) of an activity

A(I,6) = crash cost (CC) of an activity

A(I,7) = variable activity duration

A(I,8) = early start event time (ES) of an activity

A(I,9) = early finish event time (EF) of an activity

A(I,10) = late start event time (LS) of an activity

A(I,11) = late finish event time (LF) of an activity

A(I,12) = total float (TF) of an activity

A(I,13) = incremental crash cost (IC) of an activity

A(I,14) = actual duration (AD) of an activity

A(I,15) = variable activity duration

A(I,16) = activity duration difference

A(I,17) = actual total float of an activity

B(I,1) = plan material cost (PMC) of an activity

B(I,2) = plan labor cost (PLC) of an activity

B(I,3) = actual material cost (AMC) of an activity

B(I,4) = actual labor cost (ALC) of an activity

B(I,5) = variable material cost of an activity

B(I,6) = variable labor cost of an activity

B(I,7) = material cost difference of an activity

B(I,8) = material cost percent difference of an activity

B(I,9) - labor cost difference of an activity

B(I,10) = labor cost percent difference of an activity

SV = sorting variable

RC = type of event time analysis

CO = plan project duration

CX = plan total project budget cost

PATH$ = plan critical path

PO = actual project duration to date

ECP$ = actual critical path to date

PM = plan total project material cost

AM = actual total project material cost to date

MC = total material cost difference to date

PL = plan total project labor cost

AL = actual total project labor cost to date

LC = total labor cost difference to date

MD = total project material cost % difference to date

LD = total project labor cost % difference to date

SO = actual on-site overhead cost ($/day)

OO = plan on-site overhead cost ($/day)

GO = actual anticipated general overhead cost for project ($)

PG = plan anticipated general overhead cost for project (%)

OC = expected on-site overhead for project to date ($)

POC = plan on-site overhead for project to date ($)

PF = expected profit for project to date ($)

PT = plan profit for project ($)

PP = expected percent profit for project to date

PI = plan percent profit for project

X = unit cost of crashing ($/day)

Y = total cost of crashing ($)

CD = incremental cost of crashing

TS = change in an activity's plan duration to crashing

SC = selective crashing mode

4.5 Limitations of the Program

According to the dimension instructions that allocate space for arrays and specify the maximum subscript values, the following limitations were created:

-- Maximum number of activities = 99 (M%) (including dummy activities)

-- Maximum number of activity code letters for all activities = 255 (AC_T)

-- All input is integer except for durations which are single precision and activity codes which are strings.

-- All individual input value restrictions are listed under Program Description 4.1.

-- Only one crashing level may be input, but any portion of that crash level can be crashed.

4.6 Operating Instructions

A. INTRODUCTION

The SuperBrain is a one-piece microcomputer equipped with a keyboard, CRT screen, twin 5 1/4 inch disk drives and 64K of RAM memory. As you face the screen, Drive A is on the left and Drive B on the right. The power switch is on the right rear of the unit. When used, a printer is plugged into the AUXILIARY port on the rear of the unit. Communication with other computers is accomplished through the MAIN port on the rear of the unit.

B. LOADING THE PROGRAM

1. Turn on the power switch at the rear of the unit.
2. Insert the CMS PROGRAM MASTER diskette in Drive A, label at the bottom of the diskette and label facing to the right.
3. Insert a blank formatted diskette in Drive B. (Input data are stored on this diskette.)
4. The following message should appear on the screen:

   G4K SuperBrain DOS VER 3.2 for CP/M 2.2

   A>

   If the message above does not appear within a few minutes, press both red keys at the sides of the keyboard. If the response still does not appear, see the lab assistant.
5. Enter MBASIC CMS and press RETURN.

C. USING THE PROGRAM

1. The following response should appear on the screen after step B.5 above:

MENU

A	ACTUAL DATA INPUT (INCLUDES PLAN REVIEW AND TIME VARIANCE)
C	COST VARIANCE TO DATE
D	PLAN DATA OUTPUT
E	END
P	PLAN DATA INPUT
S	SELECTIVE CRASHING (INCLUDES ACTUAL DATA RUN TO DATE)
T	ACTUAL DATA OUTPUT TO DATE (TIME VARIANCE)

SELECTION?

2. All sections of this program can be used independently as indicated above. Normally, the first selection is P (enter P and press RETURN).

3. All activities must be entered in numerical order by i node and j node (i < j). Enter the following values as defined on the screen:

   AC, i, j, D, BC, CT, CC, PMC, PLC?

   Following is the maximum value and type that can be entered:

   AC, i, j, D, BC, CT, CC, PMC, PLC? ZZZ, 999, 999, 999.9, 999999, 999.9, 999999, 999999, 999999

   ex.: AB, 12, 14, 21.7, 24385, 19.2, 26305, 11500, 12000

   Zeros can be entered for all values except AC, i, and j. Only eight commas can be entered. Do not input commas within costs. ex.: 135,000 would be entered as 135000

   Don't leave extra spaces between input values or press return more than once between activities being entered.

4. The program will now print PLAN INPUT DATA FOR VERIFICATION and ask if any activities are to be changed. If an activity is to be reentered, then the following will

appear:

AC, i, j, D, BC, CT, CC, PMC, PLC?

Input as in C.3 above.

5. Each time data are presented on the screen, the following will appear:

   HARD COPY OF RESULTS (Y/N)?

   HARD COPY means a printed copy from the printer. Y = YES. N = No. Do not answer Y unless the printer is operational.

6. From this point on, just answer questions as they appear on the screen.

7. After each selection run is completed, the program will RECYCLE back to the MENU at the beginning of the program and start over again. When any question within a run lists RECYCLE, it means return to the MENU SELECTION of C.1.

8. If A-ACTUAL DATA INPUT is selected, plan output is reviewed. Then the activity number to be updated (actual values) is entered and the following will appear:

   INPUT-ACTUAL DURATION, MATL COST, AND LABOR COST?

   Following is the maximum value and type that can be entered:

   INPUT-ACTUAL DURATION, MATL COST, AND LABOR COST? 999.9, 999999, 999999

   ex.: 22.2, 11743, 12202

9. Once plan or actual data are entered, they do not have to be entered again.

10. If S-SELECTIVE CRASHING is selected, the actual data run to

date are reviewed. Then the following for actual to date critical path activities will appear:

NO	CODE	SELECT TIME	CRASH COST	UNIT COST	TOTAL COST
-	-	-	-	-	-
-	-	-	-	-	-

The select time is the plan or actual duration to date.
The crash cost will be Ø until entered by the user.
The unit cost is the cost of crashing in $/day.
The total cost is the cost of crashing in $, which is the maximum amount that can be crashed for that activity.
The activity number to be crashed and the amount is entered. The amount (CRASH DOLLARS OVER NORMAL DOLLARS) entered is divided by the unit cost to obtain days to decrease the duration of that activity. These data are printed on the screen and used to recalculate the time, cost, and profit variance. The crash data are not stored; therefore, if the user chooses to RECYCLE, values will have to be entered again.

11. Each time the program is used, any part of the output listed under MENU can be chosen without data input. The user just answers the questions as they are presented.
12. Finally, tear off the print-out with the results, remove both diskettes and turn the power switch off.

C. SAMPLE DATA INPUT SHEET

Table 3 shows a sample data input sheet to be used with the Construction Management System Program. The description column is not entered but is presented for reference purposes.

Table 3. Sample Data Input Sheet

NO.	ACT. CODE	DESCRIPTION*	i	j	D	AD	BC	CT	CC	PMC	AMC	PLC	ALC

*Not input

CHAPTER 5

EXAMPLE 1

5.1 Data Input, Output and Results

Table 4 shows a list of activities and their activity codes to be used for a highway construction project.

Figure 6 shows the CPM network diagram for the project before data input.

Table 5 shows the plan values for each activity to be entered.

Pages 52-53 indicate plan data output.

Figure 7 shows CPM network values on the network diagram with a plan project duration of 121 days.

Table 5 also shows the actual values for activities to be entered.

Pages 55-57 indicate actual data output including cost and profit variance.

Figure 8 shows the new CPM network values on the network diagram after 77 days. As can be seen, the critical path has changed along with the activity floats and the expected project duration has increased from 121 to 127 days, although profit has increased from $11,630 to $12,668 (expected on-site overhead = $45/day and expected general overhead = $14,500).

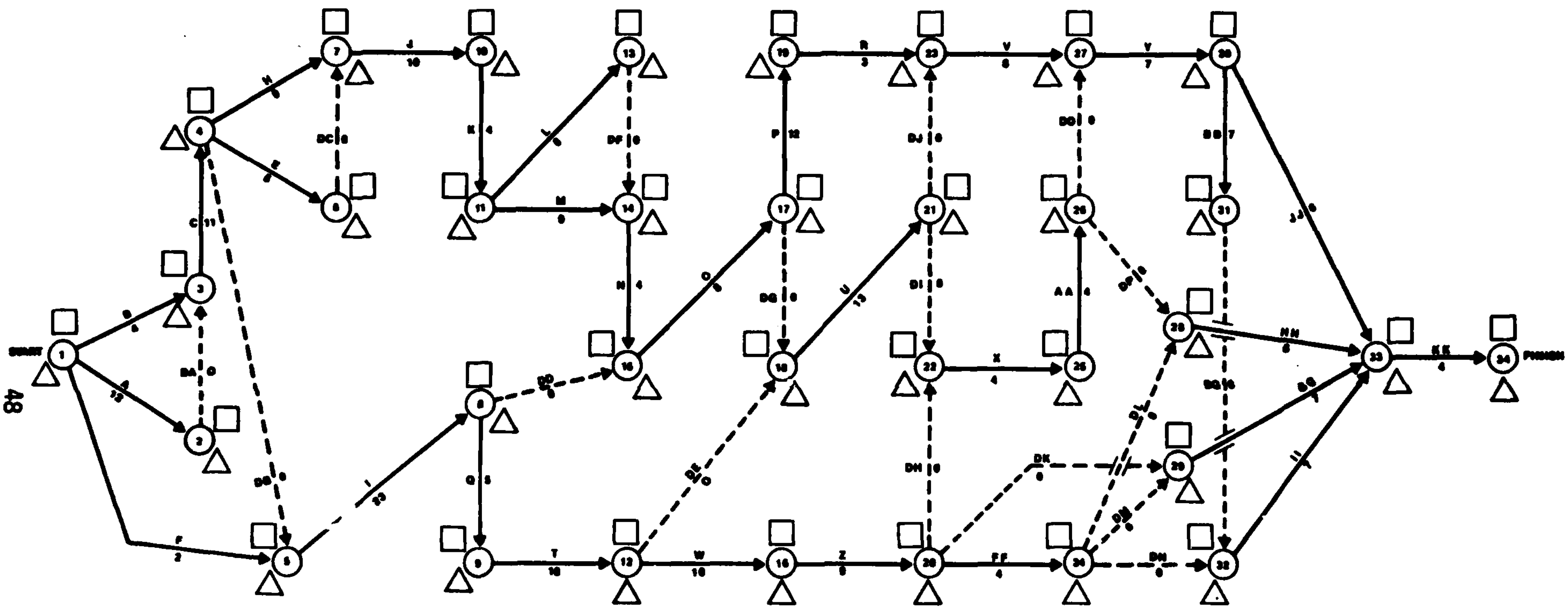
Therefore, the project manager uses selective crashing program mode and crashes the project by 6 days using crash costs and activities listed on p. 59 (output shown). The crashing yields the new CPM values and cost variance shown on pp. 60-62. The project duration is now equal

to plan, 121 days. The critical path has changed, revealing two critical paths and the expected profit has decreased to $10,758. Profit is still acceptable but below plan.

This example indicates a situation at only one point in the life of the project where action is required to keep the project duration within requirements and control costs.

Table 4. Activity Code Listing

ACT. CODE	DESCRIPTION	ACT. CODE	DESCRIPTION
A	Survey Project	P	Excavate & Fill Sect. 3
B	Mobilize	U	Grade Sect. 3
F	Move in Scrapers	R	Install Culvert Sect. 3
DA	Dummy	DH	Dummy
C	Clear Section 1	FF	Move Tank & Distributor
DB	Dummy	DK	Dummy
E	Construct Temporary Road Section 1	DI	Dummy
H	Clear Section 2	DJ	Dummy
I	Excavate & Fill Sect. 1	X	Haul Base Sect. 2
DC	Dummy	V	Grade Section 3
J	Drill & Blast Sect. 2 Phase 1	DL	Dummy
Q	Install Culvert Sect. 1	DM	Dummy
DD	Dummy	DN	Dummy
T	Grade Sect. 1	AA	Place Base Sect. 2
K	Remove Material Phase 1	DO	Dummy
L	Drill & Blast Sect. 2 Phase 2	DP	Dummy
M	Clear Sect. 3	Y	Haul Base Sect. 3
W	Haul Base Sect. 1	HH	Pave Sect. 2
DE	Dummy	GG	Pave Sect. 1
DF	Dummy	BB	Place Base Sect. 3
N	Remove Material Phase 2	JJ	Install Guardrail & Signs
O	Fill Sect. 2	DQ	Dummy
Z	Place Base Sect. 1	II	Pave Sect. 3
DG	Dummy	KK	Clean-up



LEGEND

Critical Path
Activity
Dummy
node
EET_j
LET_j

Figure 6. CPM Network Diagram Before Plan Data Input

Table 5. Values for Data Input

NO.	ACT. CODE	DESCRIPTION*	i	j	D	AD	BC	CT	CC	PMC	AMC	PLC	ALC
1	A	SURVEY	1	2	12	10	3280	10	4080	450	400	2300	2280
2	B	MOBILIZE	1	3	4	4	4600	3	5050	1800	1780	2050	2052
3	F	MOVE-EQUIP	1	5	2	4	2150	1	3000	370	400	1450	1500
4	DA	DUMMY	2	3	0	0	0	0	0	0	0	0	0
5	C	CLEAR-S1	3	4	11	8	2310	10	2670	600	450	1400	1300
6	DB	DUMMY	$	5	0	0	0	0	0	0	0	0	0
7	E	TMP-RD-S2	4	6	5	5	2750	4	3150	1500	1480	850	325
8	H	CLEAR-S2	4	7	9	9	2100	8	2430	200	200	1550	1500
9	I	EXC-FIL-S1	5	8	23	19	10500	21	12000	1350	1300	7350	6800
10	DC	DUMMY	6	7	0	0	0	0	0	0	0	0	0
11	J	D&B-S2P1	7	10	10	10	8670	9	9620	3350	3300	3900	3880
12	Q	ISTL-CV-S1	8	9	5	5	1900	4	2150	650	640	1020	1000
13	DD	DUMMY	8	15	0	0	0	0	0	0	0	0	0
14	T	GRADE-S1	9	12	18	14	9170	16	10670	2550	2320	5050	4860
15	K	RMV-MATLP1	10	11	4	11	1610	3	2060	300	550	1060	1550
16	L	D&B-S2P2	11	13	8	15	8930	6	9840	3500	4100	3950	4100

*Not input

Table 5. (continued)

NO.	ACT. CODE	DESCRIPTION*	i	j	D	AD	BC	CT	CC	PMC	AMC	PLC	ALC
17	M	CLEAR-S3	11	14	9	9	4040	8	4390	1050	1020	2300	2350
18	W	HBASE-S1	12	16	10	8	28350	8	29900	13600	13200	9900	9950
19	DE	DUMMY	12	18	0	0	0	0	0	0	0	0	0
20	DF	DUMMY	13	14	0	0	0	0	0	0	0	0	0
21	N	RMV-MATLP2	14	15	4	8	2090	3	2340	590	700	1200	1500
22	O	FILL-S2	15	17	8		6510	6	7210	2000		3430	
23	Z	PBASE-S1	16	20	9		3530	8	3880	1700		1250	
24	DG	DUMMY	17	18	0	0	0	0	0	0	0	0	0
25	P	EXC-FIL-S3	17	19	12		7960	11	8190	1950		4610	
26	U	GRADE-S2	18	19	12		7430	10	8480	2330		3800	
27	R	ISTL-CV-S3	19	23	3		1820	2	2420	1000		600	
28	DH	DUMMY	20	22	0	0	0	0	0	0	0	0	0
29	FF	TANK-DISTR	20	24	4		900	2	1800	530		250	
30	DK	DUMMY	20	29	0	0	0	0	0	0	0	0	0
31	DI	DUMMY	21	22	0	0	0	0	0	0	0	0	0
32	DJ	DUMMY	21	23	0	0	0	0	0	0	0	0	0

*Not input

Table 5. (continued)

NO.	ACT. CODE	DESCRIPTION*	i	j	D	AD	BC	CT	CC	PMC	AMC	PLC	ALC
33	X	HBASE-S2	22	25	4		4720	3	5270	2400		1720	
34	V	GRADE-S3	23	27	8		4790	7	5190	1200		2790	
35	DL	DUMMY	24	28	0	0	0	0	0	0	0	0	0
36	DM	DUMMY	24	29	0	0	0	0	0	0	0	0	0
37	DN	DUMMY	24	32	0	0	0	0	0	0	0	0	0
38	AA	PBASE-S2	25	26	4		1710	3	2160	750		710	
39	DO	DUMMY	26	27	0	0	0	0	0	0	0	0	0
40	DP	DUMMY	26	28	0	0	0	0	0	0	0	0	0
41	Y	HBASE-S3	27	30	7		23830	5	25030	11400		8600	
42	HH	PAVE-S2	28	33	6		6910	5	7760	3250		2600	
43	GG	PAVE-S1	29	33	7		16780	5	18380	7400		6550	
44	BB	PBASE-S3	30	31	7		3370	6	3790	1500		1400	
45	JJ	ISTL-GR&S	30	33	6		2320	5	3000	1500		500	
46	DQ	DUMMY	31	32	0	0	0	0	0	0	0	0	0
47	II	PAVE-S3	32	33	7		10940	4	12890	4850		4150	
48	KK	CLEAN-UP	33	34	4		5820	3	6250	1250		3650	

*Not input

TITLE: EXAMPLE 1 HIGHWAY PROJECT
DATE: 30/7/83

NO	CODE	i NODE	j NODE	PLAN DUR	BUDGET COST	CRASH TIME	CRASH COST	MATL COST	LABOR COST
1	A	1	2	12.0	3280	10.0	4080	450	2300
2	B	1	3	4.0	4600	3.0	5050	1800	2050
3	F	1	5	2.0	2150	1.0	3000	370	1450
4	DA	2	3	0.0	0	0.0	0	0	0
5	C	3	4	11.0	2310	10.0	2670	600	1400
6	DB	4	5	0.0	0	0.0	0	0	0
7	E	4	6	5.0	2750	4.0	3150	1500	850
8	H	4	7	9.0	2100	8.0	2430	200	1550
9	I	5	8	23.0	10500	21.0	12000	1350	7350
10	DC	6	7	0.0	0	0.0	0	0	0
11	J	7	10	10.0	8670	9.0	9620	3350	3900
12	Q	8	9	5.0	1900	4.0	2150	650	1020
13	DD	8	15	0.0	0	0.0	0	0	0
14	T	9	12	18.0	9170	16.0	10670	2550	5050
15	K	10	11	4.0	1610	3.0	2060	300	1060
16	L	11	13	8.0	8930	6.0	9840	3500	3950
17	M	11	14	9.0	4040	8.0	4390	1050	2300
18	W	12	16	10.0	28350	8.0	29900	13600	9900
19	DE	12	18	0.0	0	0.0	0	0	0
20	DF	13	14	0.0	0	0.0	0	0	0
21	N	14	15	4.0	2090	3.0	2340	590	1200
22	O	15	17	8.0	6510	6.0	7210	2000	3430
23	Z	16	20	9.0	3530	8.0	3880	1700	1250
24	DG	17	18	0.0	0	0.0	0	0	0
25	P	17	19	12.0	7960	11.0	8190	1950	4610
26	U	18	21	13.0	7430	10.0	8480	2330	3800
27	R	19	23	3.0	1820	2.0	2420	1000	600
28	DH	20	22	0.0	0	0.0	0	0	0
29	FF	20	24	4.0	900	2.0	1800	530	250
30	DK	20	29	0.0	0	0.0	0	0	0
31	DI	21	22	0.0	0	0.0	0	0	0
32	DJ	21	23	0.0	0	0.0	0	0	0
33	X	22	25	4.0	4720	3.0	5270	2400	1720
34	V	23	27	8.0	4790	7.0	5190	1200	2790
35	DL	24	28	0.0	0	0.0	0	0	0
36	DM	24	29	0.0	0	0.0	0	0	0
37	DN	24	32	0.0	0	0.0	0	0	0
38	AA	25	26	4.0	1710	3.0	2160	750	710
39	DO	26	27	0.0	0	0.0	0	0	0
40	DP	26	28	0.0	0	0.0	0	0	0
41	Y	27	30	7.0	23830	5.0	25030	11400	8600
42	HH	28	33	6.0	6910	5.0	7760	3250	2600
43	GG	29	33	7.0	16780	5.0	18380	7400	6550
44	BB	30	31	7.0	3370	6.0	3790	1500	1400
45	JJ	30	33	6.0	2320	5.0	3090	1500	500
46	DQ	31	32	0.0	0	0.0	0	0	0
47	II	32	33	7.0	10940	4.0	12890	4850	4150
48	KK	33	34	4.0	5820	3.0	6280	1250	3650

EVENT TIMES OF PLAN INPUT

NO	CODE	PLAN DUR	EARLY START	EARLY FINISH	LAST START	LAST FINISH	TOTAL FLOAT
1	A	12.0	0.0	12.0	0.0	12.0	0.0
2	B	4.0	0.0	4.0	8.0	12.0	8.0
3	F	2.0	0.0	2.0	21.0	23.0	21.0
4	DA	0.0	12.0	12.0	12.0	12.0	0.0
5	C	11.0	12.0	23.0	12.0	23.0	0.0
6	DB	0.0	23.0	23.0	23.0	23.0	0.0
7	E	5.0	23.0	28.0	33.0	38.0	10.0
8	H	9.0	23.0	32.0	29.0	38.0	6.0
9	I	23.0	23.0	46.0	23.0	46.0	0.0
10	DC	0.0	28.0	28.0	38.0	38.0	10.0
11	J	10.0	32.0	42.0	38.0	48.0	6.0
12	Q	5.0	46.0	51.0	46.0	51.0	0.0
13	DD	0.0	46.0	46.0	65.0	65.0	19.0
14	T	18.0	51.0	69.0	51.0	69.0	0.0
15	K	4.0	42.0	46.0	48.0	52.0	6.0
16	L	8.0	46.0	54.0	53.0	61.0	7.0
17	M	9.0	46.0	55.0	52.0	61.0	6.0
18	W	10.0	69.0	79.0	69.0	79.0	0.0
19	DE	0.0	69.0	69.0	75.0	75.0	6.0
20	DF	0.0	54.0	54.0	61.0	61.0	7.0
21	N	4.0	55.0	59.0	61.0	65.0	6.0
22	O	8.0	59.0	67.0	65.0	73.0	6.0
23	Z	9.0	79.0	88.0	79.0	88.0	0.0
24	DG	0.0	67.0	67.0	75.0	75.0	8.0
25	P	12.0	67.0	79.0	73.0	85.0	6.0
26	U	13.0	69.0	82.0	75.0	88.0	6.0
27	R	3.0	79.0	82.0	85.0	88.0	6.0
28	DH	0.0	88.0	88.0	88.0	88.0	0.0
29	FF	4.0	88.0	92.0	106.0	110.0	18.0
30	DK	0.0	88.0	88.0	110.0	110.0	22.0
31	DI	0.0	82.0	82.0	88.0	88.0	6.0
32	DJ	0.0	82.0	82.0	88.0	88.0	6.0
33	X	4.0	88.0	92.0	88.0	92.0	0.0
34	V	8.0	82.0	90.0	88.0	96.0	6.0
35	DL	0.0	92.0	92.0	111.0	111.0	19.0
36	DM	0.0	92.0	92.0	110.0	110.0	18.0
37	DN	0.0	92.0	92.0	110.0	110.0	18.0
38	AA	4.0	92.0	96.0	92.0	96.0	0.0
39	DO	0.0	96.0	96.0	96.0	96.0	0.0
40	DP	0.0	96.0	96.0	111.0	111.0	15.0
41	Y	7.0	96.0	103.0	96.0	103.0	0.0
42	HH	6.0	96.0	102.0	111.0	117.0	15.0
43	GG	7.0	92.0	99.0	110.0	117.0	18.0
44	BB	7.0	103.0	110.0	103.0	110.0	0.0
45	JJ	6.0	103.0	109.0	111.0	117.0	8.0
46	DQ	0.0	110.0	110.0	110.0	110.0	0.0
47	II	7.0	110.0	117.0	110.0	117.0	0.0
48	KK	4.0	117.0	121.0	117.0	121.0	0.0

PLAN CRITICAL PATH: A DA C DB I Q T W Z DH X AA DO Y BB DQ II KK
PLAN PROJECT DURATION: 121
BUDGET COST OF PROJECT: 201790

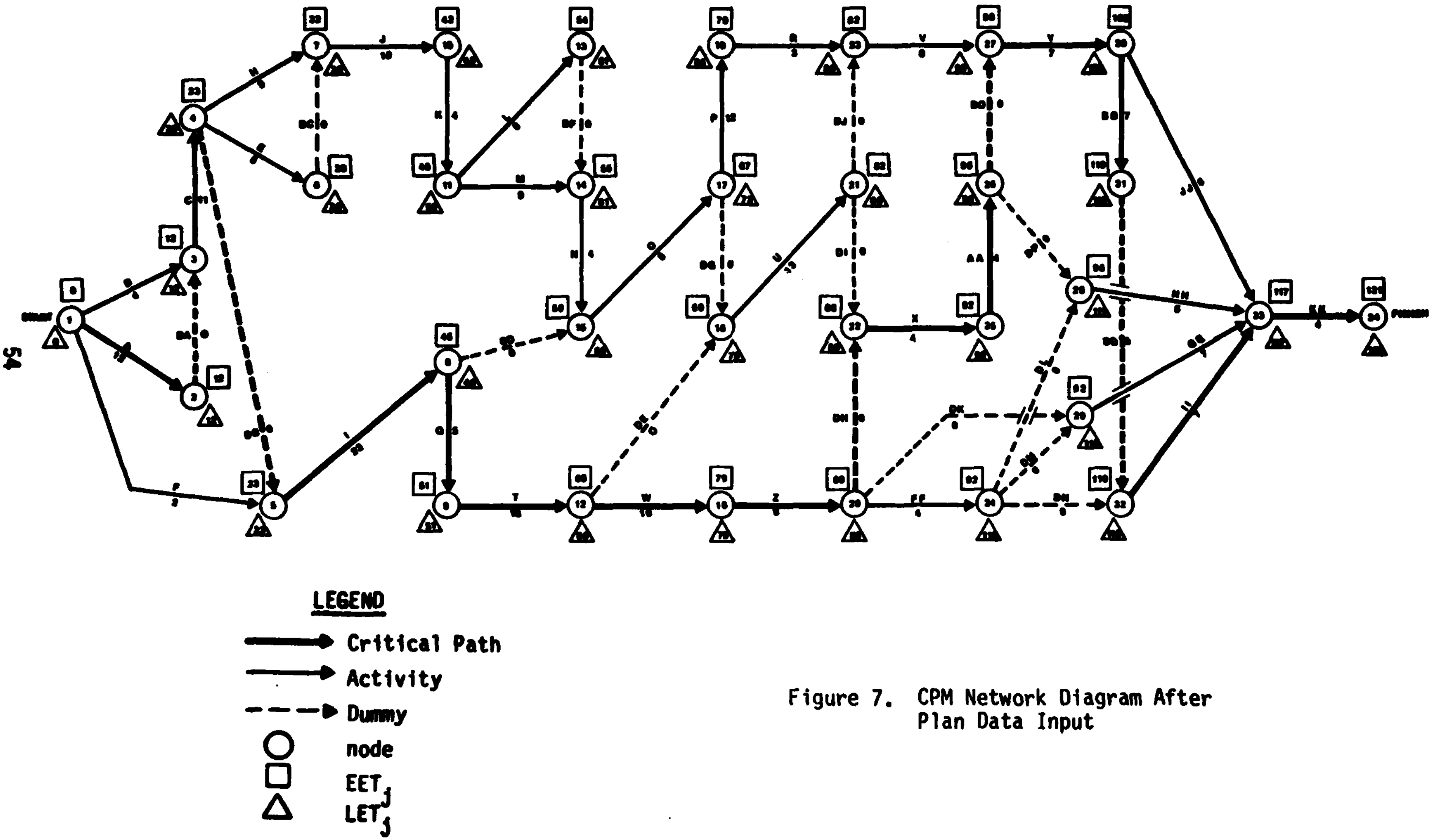


Figure 7. CPM Network Diagram After Plan Data Input

ACTUAL DATA RUN TO DATE

NO	CODE	PLAN DUR	ACTUAL DUR	DIFF	EARLY START	EARLY FIN	LAST START	LAST FIN	ACTUAL FLOAT	PLAN FLOAT
1	A	12.0	10.0	-2.0	0.0	10.0	0.0	10.0	0.0	0.0
2	B	4.0	4.0	0.0	0.0	4.0	6.0	10.0	6.0	8.0
3	F	2.0	4.0	2.0	0.0	4.0	35.0	39.0	35.0	21.0
4	DA	0.0	0.0	0.0	10.0	10.0	10.0	10.0	0.0	0.0
5	C	11.0	8.0	-3.0	10.0	18.0	10.0	18.0	0.0	0.0
6	DB	0.0	0.0	0.0	18.0	18.0	39.0	39.0	21.0	0.0
7	E	5.0	5.0	0.0	18.0	23.0	22.0	27.0	4.0	10.0
8	H	9.0	9.0	0.0	18.0	27.0	18.0	27.0	0.0	6.0
9	I	23.0	19.0	-4.0	18.0	37.0	39.0	58.0	21.0	0.0
10	DC	0.0	0.0	0.0	23.0	23.0	27.0	27.0	4.0	10.0
11	J	10.0	10.0	0.0	27.0	37.0	27.0	37.0	0.0	6.0
12	Q	5.0	5.0	0.0	37.0	42.0	58.0	63.0	21.0	0.0
13	DD	0.0	0.0	0.0	37.0	37.0	71.0	71.0	34.0	19.0
14	T	18.0	14.0	-4.0	42.0	56.0	63.0	77.0	21.0	0.0
15	K	4.0	11.0	7.0	37.0	48.0	37.0	48.0	0.0	6.0
16	L	8.0	15.0	7.0	48.0	63.0	48.0	63.0	0.0	7.0
17	M	9.0	9.0	0.0	48.0	57.0	54.0	63.0	6.0	6.0
18	W	10.0	8.0	-2.0	56.0	64.0	77.0	85.0	21.0	0.0
19	DE	0.0	0.0	0.0	56.0	56.0	81.0	81.0	25.0	6.0
20	DF	0.0	0.0	0.0	63.0	63.0	63.0	63.0	0.0	7.0
21	N	4.0	8.0	4.0	63.0	71.0	63.0	71.0	0.0	6.0
22	O	8.0	8.0	0.0	71.0	79.0	71.0	79.0	0.0	6.0
23	Z	9.0	9.0	0.0	64.0	73.0	85.0	94.0	21.0	0.0
24	DG	0.0	0.0	0.0	79.0	79.0	81.0	81.0	2.0	8.0
25	P	12.0	12.0	0.0	79.0	91.0	79.0	91.0	0.0	6.0
26	U	13.0	13.0	0.0	79.0	92.0	81.0	94.0	2.0	6.0
27	R	3.0	3.0	0.0	91.0	94.0	91.0	94.0	0.0	6.0
28	DH	0.0	0.0	0.0	73.0	73.0	94.0	94.0	21.0	0.0
29	FF	4.0	4.0	0.0	73.0	77.0	112.0	116.0	39.0	18.0
30	DK	0.0	0.0	0.0	73.0	73.0	116.0	116.0	43.0	22.0
31	DI	0.0	0.0	0.0	92.0	92.0	94.0	94.0	2.0	6.0
32	DJ	0.0	0.0	0.0	92.0	92.0	94.0	94.0	2.0	6.0
33	X	4.0	4.0	0.0	92.0	96.0	94.0	98.0	2.0	0.0
34	V	8.0	8.0	0.0	94.0	102.0	94.0	102.0	0.0	6.0
35	DL	0.0	0.0	0.0	77.0	77.0	117.0	117.0	40.0	19.0
36	DM	0.0	0.0	0.0	77.0	77.0	116.0	116.0	39.0	18.0
37	DN	0.0	0.0	0.0	77.0	77.0	116.0	116.0	39.0	18.0
38	AA	4.0	4.0	0.0	96.0	100.0	98.0	102.0	2.0	0.0
39	DO	0.0	0.0	0.0	100.0	100.0	102.0	102.0	2.0	0.0
40	DP	0.0	0.0	0.0	100.0	100.0	117.0	117.0	17.0	15.0
41	Y	7.0	7.0	0.0	102.0	109.0	102.0	109.0	0.0	0.0
42	HH	6.0	6.0	0.0	100.0	106.0	117.0	123.0	17.0	15.0
43	GG	7.0	7.0	0.0	77.0	84.0	116.0	123.0	39.0	18.0
44	BB	7.0	7.0	0.0	109.0	116.0	109.0	116.0	0.0	0.0
45	JJ	6.0	6.0	0.0	109.0	115.0	117.0	123.0	8.0	8.0
46	DQ	0.0	0.0	0.0	116.0	116.0	116.0	116.0	0.0	0.0
47	II	7.0	7.0	0.0	116.0	123.0	116.0	123.0	0.0	0.0
48	KK	4.0	4.0	0.0	123.0	127.0	123.0	127.0	0.0	0.0

ACTUAL CRITICAL PATH NOW: A DA C H J K L DF N O P R V Y BB DQ II KK
PLAN CRITICAL PATH: A DA C DB I Q T W Z DH X AA DO Y BB DQ II KK
EXPECTED PROJECT DURATION TO DATE: 127
ORIGINAL PLAN DURATION: 121

COST VARIANCE TO DATE

NO	CODE	ACT DUR DIFF	PLAN BUDGT COST	PLAN MATL COST	ACT MATL COST	MATL COST DIFF	MATL % DIFF	PLAN LABOR COST	ACT LABOR COST	LABOR COST DIFF	LABOR % DIFF
1	A	-2.0	3280	450	400	-50	-11.1	2300	2280	-20	-0.9
2	B	0.0	4600	1800	1780	-20	-1.1	2050	2052	2	0.1
3	F	2.0	2150	370	400	30	8.1	1450	1500	50	3.4
4	DA	0.0	0	0	0	0	0.0	0	0	0	0.0
5	C	-3.0	2310	600	450	-150	-25.0	1400	1300	-100	-7.1
6	DB	0.0	0	0	0	0	0.0	0	0	0	0.0
7	E	0.0	2750	1500	1480	-20	-1.3	850	825	-25	-2.9
8	H	0.0	2100	200	200	0	0.0	1550	1500	-50	-3.2
9	I	-4.0	10500	1350	1300	-50	-3.7	7350	6800	-550	-7.5
10	DC	0.0	0	0	0	0	0.0	0	0	0	0.0
11	J	0.0	8670	3350	3300	-50	-1.5	3900	3880	-20	-0.5
12	Q	0.0	1900	650	640	-10	-1.5	1020	1000	-20	-2.0
13	DD	0.0	0	0	0	0	0.0	0	0	0	0.0
14	T	-4.0	9170	2550	2320	-230	-9.0	5050	4860	-190	-3.8
15	K	7.0	1610	300	550	250	83.3	1060	1550	490	46.2
16	L	7.0	8930	3500	4100	600	17.1	3950	4100	150	3.8
17	M	0.0	4040	1050	1020	-30	-2.9	2300	2350	50	2.2
18	W	-2.0	28350	13600	13200	-400	-2.9	9900	9950	50	0.5
19	DE	0.0	0	0	0	0	0.0	0	0	0	0.0
20	DF	0.0	0	0	0	0	0.0	0	0	0	0.0
21	N	4.0	2090	590	700	110	18.6	1200	1500	300	25.0
22	O	0.0	6510	2000	2000	0	0.0	3430	3430	0	0.0
23	Z	0.0	3530	1700	1700	0	0.0	1250	1250	0	0.0
24	DG	0.0	0	0	0	0	0.0	0	0	0	0.0
25	P	0.0	7960	1950	1950	0	0.0	4610	4610	0	0.0
26	U	0.0	7430	2330	2330	0	0.0	3800	3800	0	0.0
27	R	0.0	1820	1000	1000	0	0.0	600	600	0	0.0
28	DH	0.0	0	0	0	0	0.0	0	0	0	0.0
29	FF	0.0	900	530	530	0	0.0	250	250	0	0.0
30	DK	0.0	0	0	0	0	0.0	0	0	0	0.0
31	DI	0.0	0	0	0	0	0.0	0	0	0	0.0
32	DJ	0.0	0	0	0	0	0.0	0	0	0	0.0
33	X	0.0	4720	2400	2400	0	0.0	1720	1720	0	0.0
34	V	0.0	4790	1200	1200	0	0.0	2790	2790	0	0.0
35	DL	0.0	0	0	0	0	0.0	0	0	0	0.0
36	DM	0.0	0	0	0	0	0.0	0	0	0	0.0
37	DN	0.0	0	0	0	0	0.0	0	0	0	0.0
38	AA	0.0	1710	750	750	0	0.0	710	710	0	0.0
39	DO	0.0	0	0	0	0	0.0	0	0	0	0.0
40	DP	0.0	0	0	0	0	0.0	0	0	0	0.0
41	Y	0.0	23830	11400	11400	0	0.0	8600	8600	0	0.0
42	HH	0.0	6910	3250	3250	0	0.0	2600	2600	0	0.0
43	GG	0.0	16780	7400	7400	0	0.0	6550	6550	0	0.0
44	BB	0.0	3370	1500	1500	0	0.0	1400	1400	0	0.0
45	JJ	0.0	2320	1500	1500	0	0.0	500	500	0	0.0
46	DQ	0.0	0	0	0	0	0.0	0	0	0	0.0
47	II	0.0	10940	4850	4850	0	0.0	4150	4150	0	0.0
48	KK	0.0	5820	1250	1250	0	0.0	3650	3650	0	0.0
TOTALS			201790	76870	76850	-20	-0.0	91940	92057	117	0.1

ACTUAL CRITICAL PATH NOW: A DA C H J K L DF N O P R V BB DQ II KK

PLAN CRITICAL PATH: A DA C DB I Q T W Z DH X AA DO Y BB DQ II KK

EXPECTED PROJECT DURATION TO DATE: 127

ORIGINAL PLAN DURATION: 121

EXPECTED ON-SITE OVERHEAD TO DATE: $ 5715
PLAN ON-SITE OVERHEAD COST: $ 6350
ANTICIPATED GENERAL OVERHEAD TO DATE: $ 14500
PLAN GENERAL OVERHEAD COST: $ 15000

EXPECTED PROFIT TO DATE: $ 12668
PLAN PROFIT: $ 11630
EXPECTED PERCENT PROFIT TO DATE: 6.28
PLAN PERCENT PROFIT: 5.76

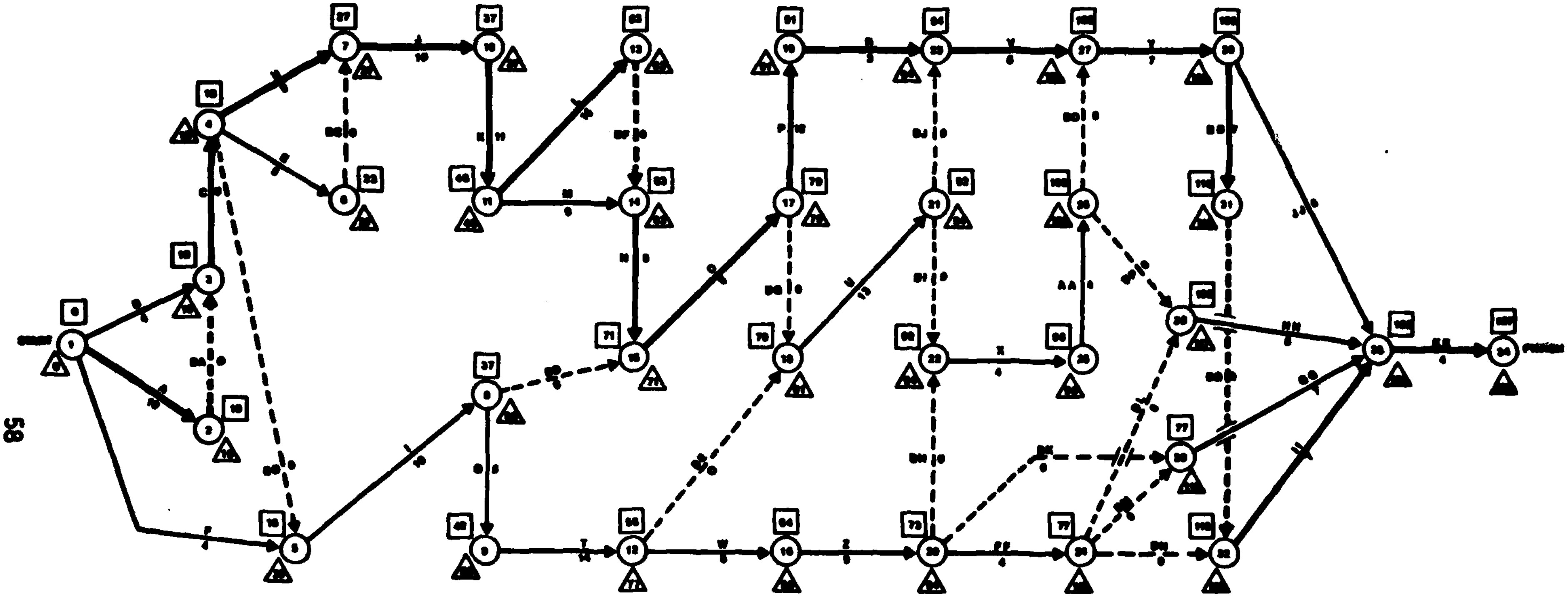


Figure 8. CPM Network Diagram at Day 77

NO	CODE	SELECT TIME	CRASH COST	UNIT COST	TOTAL COST
1	A	10	0	400	800
4	DA	0	0	400	800
5	C	8	0	360	360
8	H	9	0	330	330
11	J	10	0	950	950
15	K	11	0	450	450
16	L	15	0	455	910
20	DF	0	0	455	910
21	N	8	0	250	250
22	O	6	700	350	700
25	P	11	230	230	230
27	R	3	0	600	600
34	V	7	400	400	400
41	Y	7	0	600	1200
44	BB	6	420	420	420
46	DQ	0	0	420	420
47	II	7	0	650	1950
48	KK	3	430	430	430

ACTUAL DATA RUN TO DATE
WITH SELECTIVE CRASHING

NO	CODE	PLAN DUR	ACTUAL DUR	DIFF	EARLY START	EARLY FIN	LAST START	LAST FIN	ACTUAL FLOAT	PLAN FLOAT
1	A	12.0	10.0	-2.0	0.0	10.0	0.0	10.0	0.0	0.0
2	B	4.0	4.0	0.0	0.0	4.0	6.0	10.0	6.0	8.0
3	F	2.0	4.0	2.0	0.0	4.0	31.0	35.0	31.0	21.0
4	DA	0.0	0.0	0.0	10.0	10.0	10.0	10.0	0.0	0.0
5	C	11.0	8.0	-3.0	10.0	18.0	10.0	18.0	0.0	0.0
6	DB	0.0	0.0	0.0	18.0	18.0	35.0	35.0	17.0	0.0
7	E	5.0	5.0	0.0	18.0	23.0	22.0	27.0	4.0	10.0
8	H	9.0	9.0	0.0	18.0	27.0	18.0	27.0	0.0	6.0
9	I	23.0	19.0	-4.0	18.0	37.0	35.0	54.0	17.0	0.0
10	DC	0.0	0.0	0.0	23.0	23.0	27.0	27.0	4.0	10.0
11	J	10.0	10.0	0.0	27.0	37.0	27.0	37.0	0.0	6.0
12	Q	5.0	5.0	0.0	37.0	42.0	54.0	59.0	17.0	0.0
13	DD	0.0	0.0	0.0	37.0	37.0	71.0	71.0	34.0	19.0
14	T	18.0	14.0	-4.0	42.0	56.0	59.0	73.0	17.0	0.0
15	K	4.0	11.0	7.0	37.0	48.0	37.0	48.0	0.0	6.0
16	L	8.0	15.0	7.0	48.0	63.0	48.0	63.0	0.0	7.0
17	M	9.0	9.0	0.0	48.0	57.0	54.0	63.0	6.0	6.0
18	W	10.0	8.0	-2.0	56.0	64.0	73.0	81.0	17.0	0.0
19	DE	0.0	0.0	0.0	56.0	56.0	77.0	77.0	21.0	6.0
20	DF	0.0	0.0	0.0	63.0	63.0	63.0	63.0	0.0	7.0
21	N	4.0	8.0	4.0	63.0	71.0	63.0	71.0	0.0	6.0
22	O	8.0	6.0	-2.0	71.0	77.0	71.0	77.0	0.0	6.0
23	Z	9.0	9.0	0.0	64.0	73.0	81.0	90.0	17.0	0.0
24	DG	0.0	0.0	0.0	77.0	77.0	77.0	77.0	0.0	8.0
25	P	12.0	11.0	-1.0	77.0	88.0	77.0	88.0	0.0	6.0
26	U	13.0	13.0	0.0	77.0	90.0	77.0	90.0	0.0	6.0
27	R	3.0	3.0	0.0	88.0	91.0	88.0	91.0	0.0	6.0
28	DH	0.0	0.0	0.0	73.0	73.0	90.0	90.0	17.0	0.0
29	FF	4.0	4.0	0.0	73.0	77.0	107.0	111.0	34.0	18.0
30	DK	0.0	0.0	0.0	73.0	73.0	111.0	111.0	38.0	22.0
31	DI	0.0	0.0	0.0	90.0	90.0	90.0	90.0	0.0	6.0
32	DJ	0.0	0.0	0.0	90.0	90.0	91.0	91.0	1.0	6.0
33	X	4.0	4.0	0.0	90.0	94.0	90.0	94.0	0.0	0.0
34	V	8.0	7.0	-1.0	91.0	98.0	91.0	98.0	0.0	6.0
35	DL	0.0	0.0	0.0	77.0	77.0	112.0	112.0	35.0	19.0
36	DM	0.0	0.0	0.0	77.0	77.0	111.0	111.0	34.0	18.0
37	DN	0.0	0.0	0.0	77.0	77.0	111.0	111.0	34.0	18.0
38	AA	4.0	4.0	0.0	94.0	98.0	94.0	98.0	0.0	0.0
39	DO	0.0	0.0	0.0	98.0	98.0	98.0	98.0	0.0	0.0
40	DP	0.0	0.0	0.0	98.0	98.0	112.0	112.0	14.0	15.0
41	Y	7.0	7.0	0.0	98.0	105.0	98.0	105.0	0.0	0.0
42	HH	6.0	6.0	0.0	98.0	104.0	112.0	118.0	14.0	15.0
43	GG	7.0	7.0	0.0	77.0	84.0	111.0	118.0	34.0	18.0
44	BB	7.0	6.0	-1.0	105.0	111.0	105.0	111.0	0.0	0.0
45	JJ	6.0	6.0	0.0	105.0	111.0	112.0	118.0	7.0	8.0
46	DQ	0.0	0.0	0.0	111.0	111.0	111.0	111.0	0.0	0.0
47	II	7.0	7.0	0.0	111.0	118.0	111.0	118.0	0.0	0.0
48	KK	4.0	3.0	-1.0	118.0	121.0	118.0	121.0	0.0	0.0

ACTUAL CRITICAL PATH NOW: A DA C H J K L DF N O DG P U
DI X V AA DO Y BB DQ II KK
(WITH SELECTIVE CRASHING)
PLAN CRITICAL PATH: A DA C DB I Q T W Z DH X AA DO Y BB
DQ II KK
EXPECTED PROJECT DURATION TO DATE: 121
(WITH SELECTIVE CRASHING)
ORIGINAL PLAN DURATION: 121

COST VARIANCE TO DATE
WITH SELECTIVE CRASHING

NO	CODE	ACT DUR DIFF	PLAN BUDGT COST	PLAN MATL COST	ACT MATL COST	MATL COST DIFF	MATL % DIFF	PLAN LABOR COST	ACT LABOR COST	LABOR COST DIFF	LABOR % DIFF
1	A	-2.0	3280	450	400	-50	-11.1	2300	2280	-20	-0.9
2	B	0.0	4600	1800	1780	-20	-1.1	2050	2052	2	0.1
3	F	2.0	2150	370	400	30	8.1	1450	1500	50	3.4
4	DA	0.0	0	0	0	0	0.0	0	0	0	0.0
5	C	-3.0	2310	600	450	-150	-25.0	1400	1300	-100	-7.1
6	DB	0.0	0	0	0	0	0.0	0	0	0	0.0
7	E	0.0	2750	1500	1480	-20	-1.3	850	825	-25	-2.9
8	H	0.0	2100	200	200	0	0.0	1550	1500	-50	-3.2
9	I	-4.0	10500	1350	1300	-50	-3.7	7350	6800	-550	-7.5
10	DC	0.0	0	0	0	0	0.0	0	0	0	0.0
11	J	0.0	8670	3350	3300	-50	-1.5	3900	3880	-20	-0.5
12	Q	0.0	1900	650	640	-10	-1.5	1020	1000	-20	-2.0
13	DD	0.0	0	0	0	0	0.0	0	0	0	0.0
14	T	-4.0	9170	2550	2320	-230	-9.0	5050	4860	-190	-3.8
15	K	7.0	1610	300	550	250	83.3	1060	1550	490	46.2
16	L	7.0	8930	3500	4100	600	17.1	3950	4100	150	3.8
17	M	0.0	4040	1050	1020	-30	-2.9	2300	2350	50	2.2
18	W	-2.0	28350	13600	13200	-400	-2.9	9900	9950	50	0.5
19	DE	0.0	0	0	0	0	0.0	0	0	0	0.0
20	DF	0.0	0	0	0	0	0.0	0	0	0	0.0
21	N	4.0	2090	590	700	110	18.6	1200	1500	300	25.0
22	O	-2.0	6510	2000	2000	0	0.0	3430	3430	0	0.0
23	Z	0.0	3530	1700	1700	0	0.0	1250	1250	0	0.0
24	DG	0.0	0	0	0	0	0.0	0	0	0	0.0
25	P	-1.0	7960	1950	1950	0	0.0	4610	4610	0	0.0
26	U	0.0	7430	2330	2330	0	0.0	3800	3800	0	0.0
27	R	0.0	1820	1000	1000	0	0.0	600	600	0	0.0
28	DH	0.0	0	0	0	0	0.0	0	0	0	0.0
29	FF	0.0	900	530	530	0	0.0	250	250	0	0.0
30	DK	0.0	0	0	0	0	0.0	0	0	0	0.0
31	DI	0.0	0	0	0	0	0.0	0	0	0	0.0
32	DJ	0.0	0	0	0	0	0.0	0	0	0	0.0
33	X	0.0	4720	2400	2400	0	0.0	1720	1720	0	0.0
34	V	-1.0	4790	1200	1200	0	0.0	2790	2790	0	0.0
35	DL	0.0	0	0	0	0	0.0	0	0	0	0.0
36	DM	0.0	0	0	0	0	0.0	0	0	0	0.0
37	DN	0.0	0	0	0	0	0.0	0	0	0	0.0
38	AA	0.0	1710	750	750	0	0.0	710	710	0	0.0
39	DO	0.0	0	0	0	0	0.0	0	0	0	0.0
40	DP	0.0	0	0	0	0	0.0	0	0	0	0.0
41	Y	0.0	23830	11400	11400	0	0.0	8600	8600	0	0.0
42	HH	0.0	6910	3250	3250	0	0.0	2600	2600	0	0.0
43	GG	0.0	16780	7400	7400	0	0.0	6550	6550	0	0.0
44	BB	-1.0	3370	1500	1500	0	0.0	1400	1400	0	0.0
45	JJ	0.0	2320	1500	1500	0	0.0	500	500	0	[illegible]
46	DQ	0.0	0	0	0	0	0.0	0	0	0	0.0
47	II	0.0	10940	4850	4850	0	0.0	4150	4150	0	0.0
48	KK	-1.0	5820	1250	1250	0	0.0	3650	3650	0	0.0
TOTALS			201790	76870	76850	-20	-0.0	91940	92057	117	0.1

ACTUAL CRITICAL PATH NOW: A DA C H J K L DF N O DG P U
DI X V AA DO Y BB DQ II KK
(WITH SELECTIVE CRASHING)
PLAN CRITICAL PATH: A DA C DB I Q T W Z DH X AA DO Y BB
DQ II KK
EXPECTED PROJECT DURATION TO DATE: 121
(WITH SELECTIVE CRASHING)
ORIGINAL PLAN DURATION: 121

```
INCREMENTAL CRASH COST FOR PROJECT: $ 2180
EXPECTED ON-SITE OVERHEAD TO DATE: $ 5445
 (WITH SELECTIVE CRASHING)
PLAN ON-SITE OVERHEAD COST: $ 6050
ANTICIPATED GENERAL OVERHEAD TO DATE: $ 14500
PLAN GENERAL OVERHEAD COST: $ 15000

EXPECTED PROFIT TO DATE: $ 10758
 (WITH SELECTIVE CRASHING)
PLAN PROFIT: $ 11930
EXPECTED PERCENT PROFIT TO DATE:     5.33
 (WITH SELECTIVE CRASHING)
PLAN PERCENT PROFIT:     5.91
```

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

This program is written as simply as possible with clear, straightforward output so that the program can be used by anyone with a basic knowledge of CPM networks. The program provides time and cost information to be used as a tool for the project manager in order to make management decisions.

It is recommended that this program be used not only for progressive project control but also as the basis for periodic reports up and down the management chain. This program would also be an excellent source of historical data.

In order to obtain more detailed information from this system program, the original planned CPM network should be as specific as possible with each activity broken down as far as possible.

It is also recommended that further research and improvements be made to this system as follows:

1. Increase the capacity of the program to more than 99 activities.
2. Expand the selective crashing capabilities of the program to two or more crash levels.
3. Increase the string memory capacity of the program to more than 255 characters.
4. Break down on-site and general (office) overhead costs in order to list individual indirect costs.

5. Implement the use of this program on actual construction to determine additional information that could be effectively utilized by project managers.

CHAPTER 7

REFERENCES

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3. Parker, H. W., and Oglesby, C. H., Methods Improvement for Construction Managers. McGraw-Hill Book Company, New York, 1972.

4. Merritt, F. S., Standard Handbook for Civil Engineers, Second Edition. McGraw-Hill Book Company, New York, 1976.

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